SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT
San Juan River and Lake Powell Gold King Mine Incident Utah

Prepared for:

Utah Department of Environmental Quality
Division of Water Quality

Prepared by:

Tetra Tech, Inc.
10711 Red Run Blvd., Suite 105
Owings Mills MD, 21117

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LIST OF ACRONYMS

Ag = Silver
Al = Aluminum
As = Arsenic
Ba = Barium
BAF = Bioaccumulation Factor
B_{CF} = Bioconcentration Factor
Be = Beryllium
BERA = Baseline Ecological Risk Assessment
BW = Body Weight
Ca = Calcium
Cd = Cadmium
CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
C_f = Concentration in food
C_i = Concentration of the i^{th} PCDD/PCDF congener
Cl^- = Chloride
Co = Cobalt
COPC = Constituent of Potential Concern
Cr = Chromium
C_s = Concentration in soil/sediment
CSMRA = Conceptual Site Model for Risk Assessment
Cu = Copper
EQ = Ecological Quotient
EQ_{max} = Ecological Quotient from the maximum concentration
ERA = Ecological Risk Assessment
EPC = Exposure Point Concentration
ESV = Ecological Screening Value
Fe = Iron
F_f = Total daily feeding rate
FIR = Food Intake Rate
Hg = Mercury
HQ = Hazard Quotient
HQ_L = Hazard Quotient using the LOAEL
HQ_N = Hazard Quotient using the NOAEL
K = Potassium
LOAEL = Lowest Observed Adverse Effect Level
Mg = Magnesium
Mn = Manganese
Mo = Molybdenum
Na = Sodium
Ni = Nickel
NO_3^-,NO_2^- as N = Nitrate/Nitrite as Nitrogen
NOAEL = No Observed Adverse Effect Level

Pb = Lead
RCRA = Resource Conservation and Recovery Act
ROC = Receptors of Concern
Sb = Antimony
Se = Selenium
SLERA = Screening Level Ecological Risk Assessment
SMDP = Scientific Management Decision Points
SO_4^- = Sulfate
Tl = Thallium
TRV = Toxicity Reference Value
U = Habitat usage factor
UDEQ = Utah Department of Environmental Quality
USEPA = United States Environmental Protection Agency
USGS = United States Geological Society
V = Vanadium
$[X]_{medium}$ = concentration of COPC in specific medium
Zn = Zinc

EXECUTIVE SUMMARY

On behalf of Utah Department of Environmental Quality (UDEQ), a screening level ecological risk assessment (SLERA) was completed for the San Juan River (SJR) from the border with Colorado to Lake Powell to evaluate potential ecological risks from the Gold King Mine (GKM) spill of August 2015 in surface waters and sediments. This SLERA represents Steps 1 and 2 in the Ecological Risk Assessment (ERA) process (United States Environmental Protection Agency [USEPA] 1997a). Steps 1 and 2 of the ERA process serve as an initial screening designed to conservatively estimate the likelihood of ecological risk. The SLERA evaluated potential exposure of GKM constituents to lower-trophic level organisms including fish and invertebrates via a direct toxicity comparison of constituent concentrations to Utah Water Quality Standards and literature-based ecological screening values (ESVs). Upper-trophic level organisms, including amphibians, aquatic-dependent birds and mammals were evaluated with a food web analysis that relates measured concentration to daily dosage due to bioaccumulation from ingestion. A total of 28 surface water constituents and 25 sediment constituents were screened in this SLERA.

The available data was evaluated based on the timing of the GKM plume entering Utah in the SJR (USEPA 2017). According to USEPA's (2017) fate and transport analysis, the GKM plume entered Utah in the SJR on August 8, 2015. Surface water and sediment data on or before August 8, 2015 was considered pre-spill and data after August 8, 2015 was considered post-spill. Both sets of data were evaluated in the SLERA to determine 1) risk associated with surface water and sediment prior to the GKM spill entering Utah and 2) the degree to which the risk increased due to the GKM spill. The first two steps of the ERA process are inherently conservative to avoid minimizing risk. If a constituent is not flagged as having potential risk during Step 1 or 2 of the EPA SLERA process, then it is removed from any further evaluations due to the conservativeness of Steps 1 and 2.

Step 1 of the SLERA compares study area pre-spill and post-spill constituent concentrations in sediment and surface water to established ecological screening values (ESVs) for sediment and Utah water quality standards for surface water. If the ratio of the exposure point concentration (EPC) or the maximum measured media concentration to the ESV exceeded 1.0 then that constituent was identified as a constituent of potential concern (COPC). Constituents lacking ESVs were also retained as COPCs. The Step 1 analysis is conservative; therefore, all constituents that may potentially present risk to ecological receptors are included. The post-spill results of the Step 1 analysis resulted in the identification of the dissolved fraction of 14 surface water COPCs, the total fraction of 1 surface water COPCs, and 2 sediment COPCs that were further evaluated in Step 2. Surface water COPCs included: aluminum (Al), barium (Ba), beryllium (Be), calcium (Ca), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), nitrate/nitrite/nitrogen-N (NO_3^-,NO_2^- as N), silver (Ag), strontium (Sr), vanadium (V), and zinc (Zn). Sediment COPCs included Ba and Sr.

In Step 2 of the ERA process the lower-trophic level receptors of concern (ROC), which include aquatic water column communities of fish, aquatic invertebrates, and aquatic plants, were further evaluated because these biota are sensitive to COPCs (USEPA 2008). In addition, Step 2 of the ERA process examined the potential risk of COPCs identified in Step 1 to upper-trophic receptor species using COPC concentrations measured in the study area. Upper-trophic level ROCs, such as mammals, birds and amphibians, are physiologically susceptible to COPC toxicity and therefore were examined in Step 2 of the ERA process. Upper trophic receptors used in Step 2 of the analysis were indicator species for which appropriate data exist and they represent different types of mammals, birds, and amphibians that could inhabit the study area. Bioaccumulation of COPCs by upper-trophic level organisms and by the food they ingest was examined using a standard food web model for Step 2 analyses (USEPA 1997a). This model uses maximum sediment and surface water concentrations, as well as other conservative food web inputs (i.e., high food ingestion rate, high habitat usage factor) to characterize potential risk to biota due to surface water or sediment COPCs.

Using the maximum measured concentrations of the COPCs identified in Step 1 for the entire SJR in Utah, Al, Ba, Co, Cu, Pb, Hg, thallium (Tl), V, and Zn were identified as posing potential risk in Step 2 due to a Hazard Quotient (HQ) greater than 1.0 (calculated dosage divided by toxicity reference value based on the No Observed Adverse Effect Level).

Table ES-1. Summary of Number of COPCs Retained in Step 2 of EPA's ERA Process for the Post-Spill Analysis based on HQ greater than 1.

Media	Receptor	Post-GKM Spill COPCs Identified by ROC	Post-GKM Site 4954000	Post-GKM Site 4953990	Post-GKM Site 4953250	Post-GKM Site 4953000	Post-GKM Site 4952942	Pre-GKM Spill COPCs Identified by ROC
Surface Water	Aquatic Water-column Communities including Fish	15	12	10	9	8	5	2*
	Raccoon	5	4	5	4	4	4	5
	Muskrat	4	4	4	4	4	4	4
	Mink	7	7	6	5	4	5	6
	Mallard Duck	3	3	3	2	2	3	3
	Belted Kingfisher	4	4	3	2	2	2	4
	Great Blue Heron	4	4	3	2	2	2	4
	Bullfrog	7	7	6	6	5	3	6
Sediment	Benthic Invertebrates/Aquatic Plants	2	2	2	2	2	2	1
	Raccoon	1	1	1	1	1	1	1
	Muskrat	1	1	1	1	1	1	1
	Mink	1	1	1	1	1	1	1
	Mallard Duck	1	1	1	1	1	1	1
	Belted Kingfisher	1	1	1	1	1	1	1
	Great Blue Heron	1	1	1	1	1	1	1
	Bullfrog	1	1	1	1	1	1	1

*many of the constituents associated with the GKM spill and measured post-spill, were not measure prior to the spill.

As a standard component of the ERA process, an evaluation of the potential uncertainties and data gaps surrounding the Step 1 and 2 SLERA was completed. Results of the Step 2 analyses should be treated with caution as there are many uncertainties and conservative assumptions that were not addressed using the screening food-web model. The review of the surface water and sediment data provided by UDEQ indicated two major areas of data gaps: inadequate surface water or sediment data for screening for some sampling locations and lack of robustness in the pre-spill sediment data. Certain sampling locations including 4953940 SRJ above Lake Powell lacked full analysis of all chemicals of potential concern, thus surface water and sediment concentrations were unable to be screened. The background sediment data was limited to one pre-spill sampling effort collected on August 8, 2015 just before the Gold King Mine plume entered Utah. As sediment concentrations are not expected to potentially change as often as surface water concentrations, the lack of more than one sampling effort may not have limited the temporal analysis of the potential background sediment concentrations present in the SJR but the limited spatial distribution of the sediment samples may lead to an over- or an under-estimation of the maximum background sediment concentration. In terms of other conservative assumptions, simplistic bioaccumulation formulae are used in Step 2 to provide a conservative estimate of risk to upper trophic level organisms (i.e., top predators) via feeding or contact with COPCs.

The next step in the USEPA ERA process would be a baseline ERA (BERA) and would include refinements to the food web-model including potential area-specific factors. A BERA is recommended for this study area to help address the uncertainties using more realistic information regarding likely receptor exposure to COPCs. A BERA will address uncertainties regarding receptors and their exposure by including area-specific receptors of concern and a more thorough spatial evaluation of surface water/sediment COPC concentrations within the study area. The progression through further steps of the ERA process focuses the risk assessment on the study area and determines if the risk potential is likely to be significant. Findings of significant risk in the BERA would help focus remediation strategies by developing appropriate cleanup goals and providing an evaluation of the extent of the study area that has COPC concentrations above those goals.

1 INTRODUCTION

On behalf of Utah Department of Environmental Quality (DEQ), a Screening Level Ecological Risk Assessment (SLERA) was completed for the San Juan River and Lake Powell with respect to potential ecological impact from the Gold King Mine (GKM) spill in August 2015 (Figure 1). During an EPA removal assessment on August 5, 2015, approximately three million gallons of acid mine water containing mine waste sediments and heavy metals was released into Cement Creek, a tributary of the Animas River. The release flowed downstream as an orange-colored plume that became diluted as the Animas River joined the San Juan River by water releases from the Navajo Lake Dam (USEPA 2016a).

This report presents the purpose, methods, and results of the SLERA, which includes Steps 1 and 2 of EPA's Ecological Risk Assessment (ERA) process (USEPA 1998) (Figure 2). The SLERA serves as a screening, which is designed to conservatively estimate the potential of ecological risk in the SJR due to the release of constituents in the GKM spill. The SLERA was completed in accordance with the United States Environmental Protection Agency (USEPA) guidance for ERA under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (USEPA 1997a) and the USEPA's latest guidance (USEPA 1998).

The San Juan River flows from the Colorado border in southeast Utah and terminates in Lake Powell at the Arizona border in the south central portion of the state. The San Juan River flows through San Juan county Utah and is surrounded by shrub lands, deserts and forest areas (Figure 1). Other land used in the surrounding area include agriculture, mining, and residential development. Constituents from the GKM release flowed into the Animas River, and then into the San Juan River Based on USEPA's 2017 fate and transport analysis report (*Analysis of the Transport and Fate of Metals Released from the Gold King Mine in the Animas and San Juan River,* www.epa.gov/goldkingmine/fate-transport-analysis), the GKM plume in the SJR entered Utah on August 8, 2015 and continued in the SJR above Lake Powell until August 14, 2015. The known composition of the potential contaminants in the GKM plume were included in USEPA's 2017 report. The identified constituents in the GKM spill included Al, antimony (Sb), arsenic (As), Ba, Be, cadmium (Cd), Ca, chromium, Co, Cu, Fe, Pb, Mg, manganese (Mn), Hg, molybdenum (Mo), nickel (Ni), potassium (K), selenium (Se), Ag, sodium (Na), thallium (Tl), V, Zn, sulfate (SO_4^{2-}, chloride (Cl^-), fluoride (F^-), and NO_3^-,NO_2^- as N. This SLERA evaluated these COPCs in the surface waters and sediments of the entire Utah portion of the SJR prior to and after the presence of the GKM plume to determine if there was an increased level of risk associated with the GKM release. Risks were also evaluated in association with each SJR sampling location from the Colorado border to Lake Powell.

The SLERA applies relatively conservative assumptions to evaluate the potential risks to a wide range of relevant receptors. A finding of potential risk in this SLERA does not necessarily indicate actual risks to biota. Such a result may necessitate further evaluation and use of area-specific exposure data to address both the uncertainties resulting from the default conservative assumptions used to evaluate risk and to develop a more accurate assessment of risk. Given the conservative assumptions used in the SLERA a finding of little or no potential for risk indicates that ecological systems in the SJR are unlikely to be adversely affected by constituents present in the sediments or surface water. Scientific Management Decision Points (SMDP) are built into the SLERA process (USEPA 1997a) to help determine if data are sufficient to make a risk decision. The decision to proceed to additional ERA steps is part of risk management and could include refining the risk assessment in a BERA.

1.1 Objectives of Ecological Risk Assessment

The overall objective of the ERA approach is to identify and characterize current and potential threats to the environment from constituents in the study area and to identify cleanup levels that would protect those natural resources from risk (Figure 2). The functions of the ERA are to:

1) Document whether actual or potential ecological risks exist;

2) Identify which contaminants pose an ecological risk; and

3) Generate data to be used in evaluating cleanup options.

The guidance documents referenced below were developed for Superfund sites and the process is applicable to the GKM spill since it has become part of the Bonita Peak mining district Superfund site. This ERA incorporates the latest available guidance and concepts on ERA, including:

- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997a);
- *Guidelines for Ecological Risk Assessment* (USEPA 1998);
- *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (USEPA 1999a); and
- *Guidance for Developing Ecological Soil Screening Levels* (USEPA 2005).

This SLERA, conducted for constituents in the San Juan River and Lake Powell due to the Gold King Mine spill, comprises the first two steps of the USEPA's ERA process. As applied to the study area, the SLERA consisted of the following strategy:

1. Develop an initial conceptual model including biotic receptors and potential exposure pathways relevant in the SJR and Lake Powell;
2. Conduct a screening of measured constituent concentrations relative to conservative, default ecological screening values (ESVs);
3. Conduct simplistic, conservative food-web modeling/analysis for upper-trophic level ROCs that represent potential biota that may use the ecological habitats of the SJR and Lake Powell;
4. Determine if a significant risk potentially exists using conservative exposure assumptions; and
5. Identify risk drivers that may be further evaluated in subsequent steps (Phase 1 of the BERA).

1.2 Report Organization

This SLERA Report is organized to present in logical progression the methods, assumptions, and conclusions used to complete this SLERA. This SLERA Report is organized as follows:

- Section 1.0 – Introduction. Provides descriptions of the ERA Process as well as the San Juan River and Lake Powell study area, and outlines the report organization.
- Section 2.0 – Problem Formulation and Ecological Effects Evaluation. Describes the environmental setting of the study area, summarizes the available analytical data, and develops the preliminary conceptual site model.
- Section 3.0 – Step 1 COPC Screen. Describes the development of COPCs by screening constituents against established ecological screening values.
- Section 4.0 – Step 2 Ecological Risk Assessment. Describes the methods and results of the assessment of ecological risk based on a simplistic food-web model using indicator receptors of concern and conservative model assumptions.
- Section 5.0 – Uncertainties Associated with the Step 2 ERA. Identifies and discusses the sources of uncertainty in the ERA and evaluates their potential impacts on risk potential in the study area.
- Section 6.0 – Ecological Risk Summary. Summarizes the conclusions of the ERA for Steps 1 and 2.
- Section 7.0 – Recommendations. Discusses critical factors driving the calculated risk and recommendations on next steps.
- Section 8.0 – References. Lists all references cited in the report.

2 PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

The problem formulation represents the scoping stage of an ERA. In this step, existing information was examined, ROCs were identified, a conceptual site model (CSM) was developed to identify potential exposure pathways, and preliminary assessment and measurement endpoints were identified. Ultimately, the problem formulation generates hypotheses regarding impacts from the GKM spill to the environment. These hypotheses were tested by collecting information during the analysis phase. The ecological significance of the results was evaluated during risk characterization. The following specific elements are addressed in the problem formulation and ecological effects evaluation, and are discussed in detail below:

- Environmental setting of the SJR;
- Development of a CSM;
- Selection of ROCs;
- Potential exposure mechanisms; and
- Assignment of assessment and measurement endpoints.

2.1 Environmental Setting

The San Juan River is approximately 616 km long and drains an area of about 64,000 km^2 (Ramboll 2016). It is a major tributary of the Colorado River in the Upper Colorado River Basin. The river originates in the San Juan Mountains of southwestern Colorado, which are chiefly composed of Tertiary age rocks (Iorns et al. 1965). The soils in the SJR Basin have been principally developed by weathering of the underlying rocks. Because of the arid climate in the ecoregion, the soils are poorly developed and retain many of the geochemical characteristics of the parent rocks (Abell 1994). The SJR flows from the headwaters in the San Juan Mountains southwesterly into New Mexico northeast of Farmington, turns northwest and enters Utah after cutting across the southwest corner of Colorado. The area for this study encompasses the river segment that flows from the Utah-Colorado state line westerly to empty into Lake Powell (Meyer and Moretti 1988).

The study area is located in San Juan County which is in the southeastern portion of Utah within the Colorado Plateaus Level III ecoregion. The Colorado Plateaus ecoregion consists of uplifted, eroded, and deeply dissected tableland. The cliffs, canyons, salt valleys, mesas, benches, and buttes are formed in and underlain by thick layers of sedimentary rock. The higher elevations of the ecoregion are dominated by extensive juniper-pinyon woodland and saltbush-greasewood and brackbrush communities are common at lower elevations. Warm season grasses are supported in the Colorado Plateaus by summer moisture from thunderstorms, leading to the occurrence of endemic plants and high species diversity. This ecoregion is also home to several national parks and major oil and gas fields. From the border of Utah and Colorado to Lake Powell, the SJR flows through arid canyonlands that are adjacent to semiarid benchlands and canyonlands, as well as sand deserts (Woods et al., 2001). The Level IV ecoregions of the Colorado Plateaus are depicted in Figure 3 and the three Level IV ecoregions most closely associated with the San Juan River are described below.

Arid Canyonlands Ecoregion. The SJR segment from the border of Colorado and Utah to Lake Powell flows through the arid canyonlands ecoregion of the Colorado Plateaus. This ecoregion includes the inner gorge of the Colorado River and its major tributaries, including the SJR. It is bounded by nearly vertical, canyon walls which separate the arid canyonlands from the higher, adjacent benchlands. The elevations in this ecoregion range from approximately 3,200 to 5,000 feet. The soils of the arid canyonlands are shallower and contain less moisture than those of the adjacent ecoregions within the Colorado Plateaus, consisting of entisols and aridisols (Woods et al., 2001). Blackbrush, shadscale, and drought tolerant grasses including Indian ricegrass and galleta occur here. Exposed bedrock is also common in the arid canyonlands. Average annual rainfall in the arid canyonlands ranges from about 5 to 8 inches, with the lowest amount of precipitation occurring in the deepest canyons. The arid canyonlands ecoregion has mild winters, with minimum and maximum mean January temperatures of 16 and 48 degrees Fahrenheit (F), respectively. The minimum and maximum mean July temperatures are 60 and 100 degrees Fahrenheit, respectively. Land use in the arid canyonlands consists of recreation, grazing, and habitat for wildlife. In the salt valleys near the city of Moab, land use is dominated by cropland and residential development, while the southeast is known for oil production (Woods et al., 2001).

Semiarid Benchlands and Canyonlands Ecoregion. The arid canyonlands through which the SJR flows are bordered by the adjacent semiarid benchlands and canyonlands ecorgeion, which is characterized by broad grass, shrub, and woodland-covered benches and mesas. The elevations of this ecoregion are higher than those of the arid canyonlands and range from about 5,000 to 7,000 feet (Woods et al., 2001). Bedrock exposures are common along escarpments, rims, and steep dip slopes. Soils are mostly Entisols, which are deep eolian soils composed of fine sand. These soils support warm season grasses, Mormon tea, winterfat, four-wing saltbush, and sagebrush. Additionally, fire suppression and erosion has allowed pinyon and juniper woodland to expand beyond its original range in this ecoregion. Semiarid benchlands and canyonlands receive approximately 8 to 14 inches of annual precipitation. The minimum and maximum mean temperatures in January for this ecoregion are 4 and 44 degrees Fahrenheit, respectively, and minimum and maximum mean July temperatures are 50 and 64 degrees, respectively. Land use in the semiarid benchlands and canyonlands is mostly woodland grazing and recreation, with some uranium mining, uranium processing, and oil production (Woods et al., 2001).

Sand Desert Ecoregion. The sand desert ecoregion also within the SJR watershed. Sand deserts are nearly level and contain shifting dunes, exposed sandstone bedrock, and a mantle of eolian deposits. The elevations reach approximately 4,000 to 6,000 feet. Entisols and aridisols are common, which are sandy soils with low capacity for holding water. The moisture regime is drier than in the semiarid benchlands and canyonlands, and consists of approximately 5 to 8 inches of annual precipitation (Woods et al., 2001). Vegetation is also sparser in sand deserts. Shifting sand is mostly devoid of vegetation while soils on stable sand blankets support drought-tolerant plants, which include sand dropseed, Indian ricegrass, yucca, and blackbrush. The minimum and maximum mean January temperatures in this ecoregion are 10 and 48 degrees Fahrenheit, respectively, with minimum and maximum mean July temperatures of 92 and 96 degrees Fahrenheit, respectively. Land use in this ecoregion consists of limited grazing. Additionally, some irrigated hay and grain is grown for local cattle and sheep. Carrying capacity for wildlife in the sand deserts is low, and oil and gas production occurs in the southeast (Woods et al., 2001).

2.1.1 Threatened and/or Endangered Species

The following section is based on information obtained from the U.S. Fish and Wildlife Service (USFWS), the Utah Natural Heritage Program's Biodiversity Tracking and Conservation System (BIOTICS), and the 2005 San Juan County, Utah Resource Assessment. Data obtained from USFWS was in the form of an automatically generated list of species under the USFWS jurisdiction that are known or expected to be on or near the Utah portion of the SJR based on the known or expected range of each species. When taking all of the sources into consideration, there are potentially twenty four federally listed threatened or endangered species that may occupy terrestrial or freshwater habitats near the study area. These include six mammalian species, five bird species, one reptilian species, seven fish species, and five flowering plant species.

A list of species that are known or expected to be on or near the SJR are presented in Table 1. Because species can move, and area conditions can change, the species on this list are not guaranteed to be found on or near the SJR.

2.1.2 Land Uses Surrounding the San Juan River in Utah

San Juan County is the largest county in Utah and the second largest in the United States with approximately 5.2 million acres. It is located in the south-eastern portion of Utah within the Colorado Plateau along the Arizona, Colorado, and New Mexico borders. The county is dominated by desert shrub and barren rangeland, accounting for approximately 3 million total acres, or about 58 percent of the total area. Another 38 percent of the land is covered by forest. The remaining land in San Juan County is used for grain crops, the Conservation Reserve Program, grass, pasture, and hay lands, orchards and vineyards, row crops (including a variety of field and vegetable crops), and development. A very small portion of the county (0.09%) consists of urban land uses within metropolitan areas, and 0.9 percent of the county is covered with water. The land cover and land use composition for San Juan County is presented in Table 2.

General observations for land use were reported by the 2005 San Juan County, Utah Resource Assessment, including observed complications and problems. For grass, pasture, and hay lands, complications include poor pasture condition, water quality issues, and soil compaction due to overgrazing. Additionally, invasive and noxious plants were reported as an increasing problem. For orchards and vineyards, reported issues included the need to control erosion and protect water by managing residue, nutrients, and pests. Issues on private, non-industrial forest include erosion, degraded water quality and forest productivity.

2.2 Conceptual Site Model for Ecological Risk Assessment

The conceptual site model is designed to diagrammatically and visually relate the exposure of receptor populations to potential source areas based upon physical characteristics and potential exposure pathways present in the SJR. Important components of the CSM are the identification of potential sources (both GKM spill-related sources and non-GKM spill-related sources), transport pathways, exposure media, exposure pathways and routes, and receptor groups. Actual or potential exposures of ecological receptors associated with the GKM spill are determined by identifying the most likely pathways of contaminant release and transport.

A complete exposure pathway has three components: (1) a source of chemicals (stressors) that results in a release to the environment; (2) a pathway of chemical transport through an environmental medium; and (3) an exposure or contact point between the affected medium and an ecological receptor. The main objective of the CSM in the SLERA is to identify complete and potentially significant exposure pathways that may be present.

Concentrations of metals and other inorganic constituents have been detected in surface water and sediment samples associated with the GKM plume entering Utah in August 2015. Although inorganics tend to sorb to solids and precipitate into the sediments, due to their potentially high water solubility, some inorganics may have high concentrations in surface water. Therefore, surface water and sediment are assumed to be a potentially significant pathway of exposure. The CSM and other aspects of this

SLERA focus on inorganics in surface waters and sediments. The following sections address the various aspects of the CSM depicted in Figure 4.

2.2.1 Fate and Transport Mechanisms

During the problem formulation step of the ERA process, assumptions are made about the potential for contaminants to migrate. To support these assumptions, the risk assessment identifies all potential contaminant migration pathways (for example, surface water runoff, erosion, etc.). This information is used to complete the CSM to document and illustrate what migration pathways require further assessment. Inorganics, primarily metals, are the majority contaminants identified in association with the GKM release. USEPA's (2017a) report *Analysis of the Transport and Fate of Metals Released from the Gold King Mine in the Animas and San Juan Rivers* identified the constituents that comprised the GKM release (shown in Table 3) and this information was used to select constituents to be assessed in the SLERA.

The fate and transport properties of the metal constituents in the release are highly variable. Mercury, may be slightly volatile at normal atmospheric conditions in elemental form or in its variety of organic forms (e.g., methylmercury, ethylmercury, etc.). Whereas, most other metals are present in the environment as non-volatile species in combination with a variety of anions (e.g., sulfate, chloride, nitrate, phosphate, silicate, etc.).

Adsorption and desorption of metal species to sediments can occur by one of several complex processes and is controlled and driven by the physical and chemical properties of both the metal species and the sediments. In general, low pH of the sediment increases mobility of inorganics (USEPA, 2000). Some metals are strongly adsorbed to inorganic materials while others adsorb to organic matter, and some do not adsorb to sediment. The tendency to adsorb to sediments significantly affects the movement of metals further downstream.

Several metals are known to be bioaccumulative. Of the metals identified as constituents, Cd, Cr (specifically the hexavalent Cr), Cu, Pb, Hg (specifically methyl Hg), Ni, Se, Ag, and Zn are suspected of potential bioaccumulation (USEPA, 2000). The bioaccumulative forms of Cr and Hg (hexavalent Cr and methyl Hg) were not analyzed for in samples from the SJR.

2.2.2 Sources of Inorganic Constituents

In addition to historic and current mining operations, other potential sources of inorganics in the environment may include hydraulic fracturing, centralized waste treatment facilities for oil and gas wastewater, coal-fired electric power generating stations, , natural oil seepage, industrial manufacturing facilities, publicly owned treatment plants that treat municipal sewage, and industrial facility sewage treatment plants (USEPA 2015). In the SJR basin, irrigation and mineral extraction, processing, and use have been identified as major sources of contamination. Oil, natural gas, coal operations, mining and milling have been historically important when considering the input of inorganic materials (Abell, 1994).

Along the SJR, changes in the inundation patterns of riparian areas and declines in flood periods have caused contaminants in irrigation settling ponds to enter the river. Contaminant concentration has been increased by evaporation from the irrigation ponds and decreased scouring of riparian areas caused by the lack of flooding. The San Juan Basin is naturally highly seleniferous, which exacerbates the situation and leads to concentrations of selenium in the irrigation ponds that may be dangerous to wildlife (Chischilly, 1993). Additionally, United States Geological Survey (USGS) studies in the 1990's found that increased dissolved metal concentrations were common in the SJR basin following storms and spring snowmelt because of ongoing acid mine drainage contamination from the high density of abandoned inactive mines in the headwaters (USEPA, 2016b). Other possible contributors to metal loads in the SJR include natural inputs from downstream differences in geology and sediments, permitted dischargers, and historic ore processing facilities (USEPA, 2016b).

There are several inactive and abandoned mines that exist within a two-mile radius of the Animas River headwaters, including the Upper Gold King, Sunnyside Mine/American Tunnel, Grand Mogul, Mogul, Red and Bonita, Eveline, Henrietta, Joe and John, and Lark mines. Flows of acid mine drainage between 20 and 300 gallons per minute (gpm) have been known to enter Cement Creek from some of these mines and eventually reach the Animas River. Elevated concentrations of heavy metals due to acid rock/mine drainage have thus been reported in the Animas River and many of its tributaries. This occurs through both naturally mineralized sources and mining activities. Downstream portions of the Animas River, including the San Juan River and Lake Powell, can be affected by the elevated concentrations of hazardous substances (USEPA Action Memorandum).

The constituents selected may not accurately determine the proportion of risk directly attributable to the GKM release because the concentration that receptors are exposed to or the EPC, may also include contributions from historic and ongoing releases from other sources in the Bonita Peak Mining District, other unidentified sources of constituents to the SJR, and natural sources of constituents. The uncertainties inherent with the constituent selection will be discussed at the conclusion of the risk assessment.

2.3 Receptors of Concern

In addition to direct contact with surface water or sediment, biota may be exposed to constituents in the study area that are sequestered in food items via incorporation into the food web. Through the process of trophic transfer, biota can serve as source material for transport of constituents up the food chain, exposing higher-level animals via ingestion.

As discussed in Section 2.2, the partitioning of inorganics to sediment and solubility in surface waters, indicates that organisms whose food chains are linked to contaminated surface waters or sediments (through surface water or sediment biota) will have greater exposure than those organisms with food chains linked to soils due to the lack of impact from the GKM spill on the soils surrounding the San Juan River. In addition, data indicate that aquatic plants likewise are both sensitive to inorganics, but may also bioconcentrate inorganics for uptake by herbivorous upper trophic level receptors.

As noted in Section 2.2 and Figure 4, complete exposure pathways exist for surface water and sediment in the study area. From these environmental media, COPCs could bioaccumulate in organisms that may be eaten by other consumers. Thus, exposure pathways and routes outlined in Figure 3 that are examined in this SLERA include:

- Protection of aquatic organisms that live in the water column of the San Juan River and Lake Powell by determining that constituents in surface water do not have adverse direct toxicity effects on survival and growth.

- Protection of benthic organisms including invertebrates and plants that live in the sediment of the San Juan River and Lake Powell by determining that constituents in sediment do not have adverse direct toxicity effects on survival and growth.

- Protection of birds, represented by the mallard duck; the great blue heron; and the belted kingfisher, by determining that ingestion of constituents in food items, surface water and sediment do not have unacceptable adverse impacts on survival, growth and reproduction of higher trophic levels.

- Protection of mammals, represented by the raccoon, muskrat, and mink by determining that ingestion of constituents in food items, surface water, and sediment do not have unacceptable adverse impacts on survival, growth and reproduction of higher trophic levels.

- Protection of amphibians, represented by the American bullfrog, by determining that ingestion of constituents in food items, surface water, and sediment do not have unacceptable adverse impacts on survival, growth and reproduction of higher trophic levels.

2.3.1 Indicator Receptors of Concern

Ecological ROCs used in the SLERA are typically indicator or surrogate species that are intended to represent guilds of species that are important to the ecology of the study area and that may be susceptible to inorganics. These surrogate species use similar resources such as food or habitats as those species they are intended to represent (USEPA 1997a). Ecological ROCs can be classified into three broad categories: (1) ecologically important, (2) of recreational or commercial importance, and (3) threatened and endangered species. Ecologically important species include species characteristic of certain trophic levels (e.g., primary producers, herbivores, carnivores) or species that provide a keystone role in terms of the structure or function of a given ecosystem (e.g., prairie dogs). Species recreationally important for hunting or fishing include for example, trout or deer. Threatened and endangered species are those plants and animal species listed for special protection by both the Federal and/or State government.

Species-specific attributes considered in identifying ecological ROCs for this SLERA include the following:

- Are known to occur, or are likely to occur, in the study area;
- Have a particular ecological, economic, or aesthetic value;
- Are representative of the food web and/or guild (as defined below);
- Are representative of taxonomic groups, life history traits, and/or trophic levels in the habitats for which complete exposure pathways are likely to exist;
- Can be expected to represent potentially sensitive populations because of toxicological sensitivity or potential exposure magnitude; and
- Have sufficient ecotoxicological information available on which to base an assessment.

The last criterion listed above is critical to the SLERA because risk analyses require a number of specific parameters for a given species in order to calculate potential food web exposure as shown in Section 4. Typically, such information is lacking for threatened and endangered species or species indigenous to an area, therefore requiring the use of indicator or surrogate species for which such data are available.

Given the physico-chemical properties of inorganics discussed in Section 2.2.3, indicator ROCs chosen for this SLERA represent various trophic levels and habitats for which surface water and sediment exposure of inorganics directly or indirectly is possible. For sediment- and surface water-related pathways, these include species representing aquatic communities (i.e., fish), benthic invertebrates, as well as, aquatic birds and mammals spanning several trophic levels.

Aquatic Communities --- Communities of organisms including fish and invertebrates that live in the water column of the San Juan River and Lake Powell are represented in this trophic level. Direct contact with inorganics in surface waters was evaluated.

Benthic Invertebrates/Aquatic Plants – Communities of invertebrates and plants that live in the sediments of the San Juan River and Lake Powell are represented in this trophic level. Direct contact with inorganics in the sediment was evaluated.

Aquatic Avian Species — Numerous avian species are likely to potentially utilize the aquatic habitats of the San Juan River and Lake Powell. Three aquatic avian ROCs are examined in this SLERA: the mallard duck, representative of omnivorous receptors; the great blue heron, which feeds on benthic invertebrates and fish; and the belted kingfisher, which eats fish exclusively. These three species were selected because they are known to occur or are likely to occur in the study area (i.e., mallards); are representative of taxonomic groups that may be present in the study area (i.e., ducks, herons, etc.); represent populations sensitive to inorganics (i.e., piscivorous birds); and these species have sufficient ecotoxicological information available with which to conduct risk analyses.

Aquatic Mammalian Species — Mammals can be expected to utilize the aquatic and wetland habitat of the San Juan River and Lake Powell. The omnivorous raccoon; herbivorous muskrat; and carnivorous mink were selected as a surrogate for mammalian receptors that could be found in the study area. The mink was selected because it is known to occur or likely to occur in the study area, is representative of mammals as a group, and has sufficient ecotoxicological information available with which to conduct risk analyses.

Aquatic Amphibian Species – Amphibians likely utilize the aquatic habitats of the San Juan River and Lake Powell. The American bullfrog was selected as a surrogate because it is known to occur or likely to occur in the study area, is representative of amphibians as a group, and has sufficient ecotoxicological information available with which to conduct risk analysis.

2.4 Assessment and Measurement Endpoints

USEPA (1998) guidance stresses the importance of selecting ecologically significant endpoints that will be evaluated in the ERA process. The selection of assessment endpoints is based on the fundamental knowledge of the local ecology. Based on the ROCs identified for the study area, and the types of habitat that occur in the study area, the following ecological assessment endpoints are defined (Table 4):

1. Protection of fish and other aquatic water column communities: Determine whether exposure to constituents in surface water has unacceptable adverse impacts on their survival and growth.

2. Protection of benthic invertebrate and aquatic plant communities: Determine whether exposure to constituents in sediment has unacceptable adverse impacts on their survival and growth.

3. Protection of aquatic birds, represented by the mallard duck, the great blue heron, and the belted kingfisher: Determine whether ingestion of constituents in surface water, sediment and dietary items has unacceptable adverse impacts on their survival, growth and reproduction.

4. Protection of aquatic mammals, represented by the raccoon, the muskrat, and the mink: Determine whether ingestion of constituents in surface water, sediment and dietary items has unacceptable adverse impacts on their survival, growth and reproduction.

5. Protection of amphibians, represented by the bullfrog: Determine whether ingestion of constituents in surface water, sediment and dietary items has unacceptable adverse impacts on their survival, growth and reproduction.

Measurement endpoints are measurable ecological characteristics that are related to the assessment endpoints (USEPA 1998). Because it is difficult to "measure" assessment endpoints, measurement endpoints were chosen that permit inference regarding the above described assessment endpoints. Measurement endpoints selected for this SLERA include (Table 4):

- Constituent concentrations in sediment—The measurement of constituents in sediment provides the means, when compared to appropriate sediment-screening and toxicity reference values, to assess the protection of organisms that may come in contact (direct or indirect) with the sediment.

    - Pre-spill sediment data was collected on August 8, 2015, prior to the GKM plume entering UT. One sample from each of four sampling locations (4954000 - SJR at US160 Xing in CO; 4953990 – SJR at the Town of Montezuma; 4953250 – SJR at Sand Island; and 4953000 – SJR at Mexican Hat US163 Xing) (UDEQ, 2016, Appendix Cb) (Figure 5). Inorganics measured include: Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, Ag, Na, Tl, V, and Zn.

    - Post-spill sediment data were collected on eight occasions between August 15, 2015 and February 17, 2016 and include one sample on each date from each of the four pre-spill sampling locations and one additional sampling location (4952942 – SJR at Clay Hills). The same inorganics measured pre-spill were measured in the post-spill samples.

- Inorganic concentrations in surface water—The measurement of inorganics in surface water provides the means, when compared to appropriate water quality standards and toxicity reference values, to assess the protection of organisms that may come in contact (direct or indirect) with the surface water.

    - Pre-spill surface water data was collected between 1978 and 2014 as presented in Appendix A of *Utah's Long-term Monitoring and Assessment for the San Juan River and Lake Powell Utah* (UDEQ, 2016). Up to 74 samples (range 5 – 74) from 7 sampling locations on the main stem San Juan River were used to develop pre-spill maximum concentrations (UDEQ, 2016). Inorganics measured include: Al, As, Ba, Cd, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, V, and Zn.

- Post-spill surface water data were collected on eight occasions between August 8, 2015 and July 25, 2016 and include samples from eight locations on the SJR including 4954000 – at US160 Xing in CO; 4953250 – at San Island; 4953400 – at Swinging Footbridge; 4953800 – confluence with W FK Allen; 4953900 – above Aneth; 4953950 – at Marble Wash; 4952940 – above Lake Powell and 4953000 – at Mexican Hat 163 Xing (Figure 5). Inorganics measured include: Sb, Al, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, Ag, Na, Sr, T, V, and Zn.

Measurement endpoints were used to determine EPCs. The maximum measured value for each COPC was used as the EPC across the whole SJR and the maximum measured value at each sampling location was used to examine risk in the river segments between sampling locations (Figure 5). The maximum concentration measured at each sampling location was used to evaluate risk to ROCs from that sampling location downstream to the next sampling location. By structuring the evaluation in this way, those river segments that do not indicate significant risk may be eliminated from further evaluation and those that did indicate significant risk can be identified for further evaluation of potential sinks and other sources that may contribute to the identified risk.

3 STEP 1 COPC SCREEN

This section of the SLERA identifies whether constituents are present in the study area after the GKM spill at concentrations that exceed pre-spill data and conservative ESVs. If so, then these inorganics are retained as COPCs and evaluated further in Step 2. Both surface water and sediment samples collected in the study area were analyzed for a variety of inorganics. Sample locations are illustrated in Figure 2 and summarized analytical results are provided in Appendix A. In accordance with USEPA ERA guidance, the maximum of field duplicates was used as the concentration for those particular samples when they occurred. For 'non-detect' results, the method detection limit was used as the concentration.

The screening process that identifies COPCs is environmentally conservative so as not to eliminate constituents that could pose potential ecological risk. Using conservative assumptions and appropriate screening values during the constituent screening process minimizes this potential. For each media type, the maximum constituent concentration of all sample locations across the study area and the maximum constituent concentration at each sample location was used for screening. These maximum concentrations in surface water and sediment were then compared to the ESVs for surface water (in this case the Utah water quality standards) and sediment, respectively. If the calculated hazard quotient (HQ), which is the maximum inorganic concentration divided by the ESV, was greater than 1.0, then the specific inorganic was identified as a COPC and evaluated further in Step 2 of the ERA process.

Constituents were not evaluated in Step 2 if the maximum detection (or if undetected, the method detection limit (MDL)) was less than the corresponding ESV. Constituents with no corresponding ESV were moved to the Uncertainties section (Section 5) because it is unknown at what concentration the constituent would pose a risk. Constituents identified in one media (i.e., surface water or sediment) were carried forward to Step 2 for both media. To summarize, the four possible Step 1 outcomes for an inorganic constituent are as follows:

- The constituent is detected and has an ESV for that media – move to Step 2 and identify as a COPC if the maximum detection is greater than the ESV; no further evaluation of the constituent if the maximum detection is less than the ESV;

- The constituent is not detected, but has an ESV – move the constituent to the Uncertainties section if the MDL is in excess of the ESV; no further evaluation if the MDL is less than the ESV;

- The constituent is detected, but does not have an ESV – move constituent to Uncertainties because it is unknown what concentration would pose a risk to ROCs; and

- The constituent is not detected and does not have an ESV – move the constituent to the Uncertainties section because it is unknown what concentration would pose a risk to ROCs;

3.1 Surface Water COPC Identification

ESVs for inorganic constituents in surface water are represented by Utah water quality standards for the protection of freshwater aquatic life (Table 5). When Utah did not have a water quality standard for certain inorganics, other outside sources of screening values were used including Suter and Tsao 1996, USEPA 2017b, USEPA 1996, and CCME 1999. Because some of these water quality standards are hardness-dependent, the lowest hardness on the day of the maximum COPC concentration was used to calculate the hardness-dependent water quality standards. Hardness-dependent water quality standards increase as hardness increases, thus using the lowest hardness is conservative. Hardness-dependent water quality standards include Cd, Cr, Cu, Pb, Ni, Ag, and Zn. Table 5 summarizes the surface water screening values used for Step 1 Surface Water Screening and the inorganics that were identified as COPCs using the maximum measured surface water concentration in the SJR. Table 6 summarizes the measured maximum concentrations pre-spill in the SJR and post GKM release at each of the sampling locations and indicates whether the constituent was in excess of the ESV.

3.2 Sediment COPC Identification

Sediment screening values for the identification of COPCs include those from USEPA 1995, NOAA (Buchman, 2008), USEPA 2015, and Ministry of Housing, Spatial Planning and Environment 1994 (Table 8). ESVs were available for nineteen of twenty-five constituents screened. Those constituents without ESVs included Be, Ca, K, Mg, Na, and Tl. Some of these constituents including Ca, K, Mg, and NA are essential nutrients and are generally non-toxic in sediments. These inorganics will not be evaluated further in this ERA. The other inorganics, including Be and Tl, which lacked ESVs, were moved to the Uncertainties section and discussed further. Table 9 summarizes the sediment screening values used for Step 1 Sediment Screening and the inorganics that were identified as sediment COPCs using the maximum measured sediment concentration from all five sampling locations in the SJR and LP. Table 10 summarizes the measured maximum values pre-spill in the SJR and post GKM spill at each of the sediment sampling locations in the SJR and indicates whether the concentrations were in excess of the ESV.

3.3 Summary of Ecological COPC Screening

Maximum surface water and sediment concentrations of constituents that exceeded ESVs in surface water and/or sediment were identified as COPCs. When a COPC was identified as a COPC in one media it was also carried forward in the other media. For instance, Al was identified as a COPC in surface water because the maximum concentration was in excess of the ESV, but Al was not identified as a COPC for sediment (maximum concentration = 16,600 mg/kg and ESV = 25,500 mg/kg).

Ca, Mg, K, and Na are considered essential nutrients and were not evaluated after Step 1. Ca and Mg in the surface water of the SJR at McElmo Wash (#4953880) were both in excess of their respective water quality standards, but neither is thought to be toxic even at these elevated levels. The four lacked sediment screening values and are not considered to pose potential risk.

Other COPCs including total sulfate in surface water and beryllium and thallium in sediment lacked ESVs. Although total sulfate lacked an ESV for surface water, it was not identified as a COPC for sediment and thus was moved to the Uncertainty section. Be and Tl lacked ESVs for sediment, but Be was identified in surface water as a COPC so Be will be retained and moved to Step 2, while Tl will be moved to the Uncertainty section. Although Sb was not detected in any sediment sample, the maximum detection limit was in excess of the ESV, thus Sb will be moved to the Uncertainty section and discussed further. Certain COPCs were not evaluated in Step 2 due to detected or non-detected maximum concentration being less than ESVs in both surface water and sediment including As, Cd, Cl^-, Cr, Mo, Ni, and Se. COPCs in each media that were retained and will be evaluated in Step 2 or moved to the Uncertainty section are summarized in Table 11.

As indicated in Table 7, only the pre-spill maximum surface water concentrations of Fe (5.49 mg/L) and Mn (314 µg/L) exceeded their respective ESVs. Ba was the only constituent that has a measured pre-spill sediment maximum concentration that exceeded the ESV (Table 10). In terms of evaluating the post-spill maximum at each sampling location, Table 11 summarizes the number of sampling locations that had surface water or sediment maximums greater than their respected ESVs. In sediment only Ba and Sr were greater than the ESVs and the maximum of all sampling location exceeded the ESV. For Ca, Cu, Fe, Mg, Mn, Sr, and Zn in surface water, only one sampling locations exceeded the ESV (Table 11).

4 STEP 2 ECOLOGICAL RISK ASSESSMENT

In Step 2 of the risk assessment process, conservative exposure assumptions were used to evaluate whether the COPCs identified in Step 1 may pose a risk to each ROC evaluated in Section 2. Exposure assessment is a key component of risk quantitation evaluated in Step 2, linking constituents to receptors through complete pathways. Exposure refers to the degree of contact between ecological receptors and the COPC. COPCs that are bioaccumulative are examined in upper trophic level receptor food webs where indirect contact (dietary exposure) is the most relevant exposure pathway.

In Step 2 of this SLERA, maximum SJR/LP sediment and surface water concentrations of COPCs were evaluated for indirect dietary exposure to upper trophic aquatic ROCs. These exposure pathways are described below for Step 2 of the SLERA. A toxicity assessment and risk characterization for potential aquatic ROCs is described and calculated below. Finally, a summary of the Step 2 processes and results, including a review of the scientific management decision point (SMDP), is discussed. Also completed in Step 2, COPCs were evaluated for each sampling location. The COPCs identified in Step 1 for the SJR as a whole were evaluated for each location although the Step 1 analysis for that particular location may not have identified it as a COPC.

4.1 Indirect Exposure of Higher Trophic Levels to COPCs (Food Web Analyses)

In Step 2, COPC concentrations in dietary items were conservatively calculated by multiplying the maximum sediment and surface water concentration detected in field samples by the bioaccumulation factor (BAF) or bioconcentration factor (BCF) for benthic invertebrates, plants, and fish. In keeping with EPA guidance on Step 2 screening assessment, all dietary concentrations are presented on a dry-weight basis. Using dry-weight for the calculation of dietary exposure is conservative and will overestimate the risk to upper trophic level receptors as discussed in the Uncertainties section (Section 5.0).

Consistent with EPA's Step 2 guidance, dietary exposures for ROCs were estimated as daily doses for comparison to ingestion-based toxicity reference values (TRVs) provided by Sample et al. (1996), Goel et al. (1980), ATSDR (1990a, b; 1994), Nation et al. (1983), Hill (1979), Eisler (1996), Bean and Hudson (1976), and USEPA (1995, 1997a). The daily dose for a given receptor to COPCs is determined by multiplying the total body-weight normalized feeding rate (feeding rates are based on allometric equations cited by Nagy 2001 and are based on body weight and species type) by the highest food item concentration calculated. The habitat-usage factor (U) is assumed to be equal to 1.0 (i.e., to be conservative it is assumed the receptor uses the study area for 100 percent of its food and water) for this Step 2 analysis, consistent with EPA guidelines (USEPA 1997a). Separate doses are presented for sediment, surface water, and food contributions, and then summed to produce the total dose for each ROC. The equations involved in calculating exposure are discussed in detail in sections 4.1.1 and 4.1.2.

Information relevant to the ecology of the surrogate ROCs (i.e., body weights (BW), food-ingestion rates (FIR), water-ingestion rates (WIR) and incidental sediment-ingestion rates) is included in Table 12, along with the primary sources used for these exposure parameters. The FIRs and WIRS were taken from an allometric equation used to derive FIRs and WIRs based on body weight and species type (Nagy 2001; Calder and Braun 1983). The following sections review the calculations required to estimate the indirect exposure of aquatic-dependent ROCs in the study area.

4.1.1. Aquatic (Sediment and Surface Water-Based) Food Web

The relevant pathways through which mammalian and avian ROCs dependent on aquatic-derived food are exposed to sediment and surface water concentrations of inorganics are through chronic exposure to sediment and surface water via dietary uptake. The ROCs occupy different feeding guilds (e.g., avian piscivores, mammalian herbivores), but have diets that contain potential biological transport pathways for inorganics in sediment and surface water. The Step 2 aquatic risk assessment assumes that ROCs consume only the most impacted food item (i.e., the highest concentration of a given COPC), surface water ingestion through drinking water, and incidental sediment ingestion through feeding (incidental sediment ingestion rate is a percentage of the FIR) was included in this assessment.

Bioaccumulation and bioconcentration factors for aquatic invertebrates, plants and fish were used in Step 2 for the determination of exposure by upper trophic-level aquatic ROCs (Table 13). Concentrations in fish were estimated using a conservative approach to estimate COPC dose to upper trophic aquatic-dependent birds and mammals. Fish as prey are exposed to COPCs via direct contact with sediment and surface water, as well as indirectly through the consumption of prey items.

Whole-body fish BAFs were used to estimate the concentrations of COPCs in sediment that are transferred to fish living in that system. The equation used to make this estimate is:

$$[X]_{\text{fish sediment}} = [X]_{\text{sediment}} \text{ x } BAF_{\text{sediment}}$$

where:

$[X]_{\text{fish sediment}}$ = the concentration of constituent X in fish due to direct sediment exposure

$[X]_{\text{sediment}}$ = the concentration of constituent X in the sediment

BAF = the whole-body bioaccumulation factor for constituent X in sediment

Whole-body fish BCFs were used to estimate the concentration of COPCs in surface water that is transferred to fish living in that system. The equation used to make this estimate is:

$$[X]_{\text{fish surface water}} = [X]_{\text{surface water}} \text{ x } BCF_{\text{surface water}}$$

where:

$[X]_{\text{fish surface water}}$ = the concentration of constituent X in fish due to direct surface water exposure

$[X]_{\text{surface water}}$ = the concentration of constituent X in the surface water

BCF = the whole body bioconcentration factor for constituent X in surface water

Fish, as a food source, can be exposed to sediment and surface water COPCs indirectly (via dietary uptake of prey items). The food-chain pathway (sediment/surface water → plants, invertebrates, forage fish → predator fish → birds and mammals) is the major route by which exposure to COPC in fish occurs. Fish uptake of COPCs through diet was modeled using the calculated benthic invertebrate tissue concentration and body weight normalized ingestion rate for the Cyprinidae (minnow) family of fishes. Cyprinids were modeled because they typically make up the level of forage fish that are preyed upon by predatory fish.

$$[X]_{\text{fish food}} = ([X]_{\text{benthic invertebrate}} * F_f)$$

Where:

$[X]_{\text{fish food}}$ = the whole-body concentration of constituent X in fish due to dietary exposure

$[X]_{\text{benthic invertebrate}}$ = the concentration of constituent X in benthic invertebrates (i.e., concentration in sediment multiplied by the invertebrate BAF).

F_f = Total daily feeding rate in kg food/kg-BW

Thus, the total concentration in fish from the three sources was modeled as:

$$[X]_{\text{fish total}} = [X]_{\text{fish sediment}} + [X]_{\text{fish surface water}} + [X]_{\text{fish food}}$$

As previously noted, the models used to estimate of the concentration of constituents in prey including fish are conservative because they do not account for elimination of the constituent by the organism and assume the entire concentration is bioaccumulated in the tissues.

4.1.2 Aquatic Upper Trophic Level Dosage

Upper trophic level ROCs are exposed to COPCs through direct (ingestion of sediment/surface water) and indirect (ingestion of food) exposure. As a result, a dosage calculation used for aquatic upper trophic level ROCs is described below. The total dose to upper trophic level organisms is calculated as:

$$Dose_{total} = Dose_{food} + Dose_{sediment} + Dose_{surface\ water}$$

where:

$Dose_{total}$	=	Total daily dose of COPCs received by receptor; mg COPC/kg-BW/day
$Dose_{food}$	=	Daily dose of COPCs received by receptor; mg COPC/kg-BW/day from the most impacted food item
$Dose_{sediment}$	=	Daily dose of COPCs received by receptor; mg COPC/kg-BW/day from incidentally ingested sediment
$Dose_{surface\ water}$	=	Daily dose of COPCs received by receptor; mg COPC/kg-BW/day from ingestion of surface water

The total dose from food is calculated as:

$$Dose_{food} = F_f \times U \times C_f$$

where:

F_f	=	Total daily feeding rate in kg food/kg-BW of ROC/day (wet basis). Ff is receptor-specific.
U	=	Habitat usage factor (fraction of habitat range represented by the study area) for receptor; assumed to be 1.0 for the Step 2 food web
C_f	=	Concentration of COPCs in food; calculated using the maximum determined for each impacted food item (mg COPC/kg food item)

The total dose from incidental ingestion of sediment is calculated as:

$$Dose_{sediment} = I_{sed} \times U \times C_{sed}$$

where:

C_{sed}	=	Concentration of COPCs in sediment; mg COPC/kg sediment (dry basis)
U	=	Habitat usage factor (fraction of habitat range represented by the study area) for receptor; assumed to be 1.0 for the Step 2 food web
I_{sed}	=	Total daily incidental ingestion rate for sediment in kg sediment/day (wet basis). I_{sed} is receptor-specific.

The total dose from ingestion of surface water is calculated as:

$$Dose_{surface\ water} = I_{sw} \times U \times C_{sw}$$

where:

C_{sw}	=	Concentration of COPCs in surface water; mg COPC/L surface water
U	=	Habitat usage factor (fraction of habitat range represented by the study area) for receptor; assumed to be 1.0 for the Step 2 food web
I_{sw}	=	Total daily surface water ingestion rate in L surface water/day (wet basis). I_{sw} is receptor-specific.

Information necessary to calculate total dose for a specific ROC includes: body-weight normalized food-ingestion rate (F_f) (Table 12), body-weight normalized incidental sediment-ingestion rate (I_{sed}) (Table 12), body-weight normalized water-ingestion rate (I_{sw}) (Table 12), and constituent concentration in surface water and sediment (Tables 7 and 10).

4.3 Toxicity Assessment

USEPA (1997) guidance specifies that a screening TRV should be "equivalent to a documented or best conservatively estimated chronic NOAEL" (No Observed Adverse Effect Level). Because there can be wide variation in the literature on NOAELs for a given COPC, risks were also calculated for conservatively estimated Lowest Observed Adverse Effect Levels (LOAELs) to provide upper and lower estimates of risk, based on the NOAEL and LOAEL, respectively.

Sample et al. (1996), Goel et al. (1980), ATSDR (1990a, b; 1994), Nation et al. (1983), Hill (1979), Eisler (1996), and USEPA (1995, 1997) were used as sources for NOAEL and LOAEL TRVs for mammals and birds. The selected NOAELs and LOAELs were based on relevant endpoints for chronic exposure including reproduction and developmental effects. For Step 2, the potential hazards were characterized through comparisons of calculated dose (using the maximum sediment and surface water concentration of COPCs and the most impacted food items) to the NOAEL TRVs (Table 14) and LOAEL TRVs (Table 15).

4.4 Risk Characterization for Step 2

The risk characterization portion of the SLERA used the information generated during the two previous parts of the SLERA (problem formulation and Step 1 screening to estimate potential risks to ecological receptors. Also included is an evaluation of the uncertainties associated with the models, assumptions, and methods used in the SLERA and their potential effects on the conclusions of the assessment. The main objective of risk characterization at the screening level (is to derive a list of potential ROCs that may be at risk from the COPCs identified in Step 1.

Direct toxicity associated with lower trophic levels (i.e., benthic invertebrates, aquatic plants, fish, and water column invertebrates) was evaluated using an ecological quotient based on the maximum measured media concentration divided by the ESV, termed EQ_{max}. The EQmax is different than the HQ because the EQmax is the maximum concentration divided by the ESV, where the HQ is a total dosage of exposure to upper-trophic level ROCs divided by a TRV (either a NOAEL or a LOAEL). Values of EQ_{max} that were greater than 1.0 were identified as needing further evaluation. The results are discussed below.

As part of this upper-trophic level ROC risk calculation, the exposure doses were compared with the corresponding TRVs (Tables 14 and 15) to derive risk estimates using the HQ method. HQs were calculated by dividing the constituent concentration in the medium being evaluated by the corresponding ingestion-based TRV. HQs exceeding 1.0 indicate the potential for unacceptable risk, as the constituent concentration or dose (exposure) equals or exceeds the TRV (effect). However, TRVs and exposure estimates are derived using intentionally conservative assumptions at the screening level such that HQs greater than or equal to 1.0 do not necessarily indicate that risks are present or impacts are occurring. Rather, it identifies constituent-pathway-receptor combinations that may require further evaluation using more realistic exposure scenarios and assumptions. Following the same reasoning, HQs less than one indicate that risks are unlikely, enabling a conclusion of negligible risk to be reached with high confidence. The Step 2 exposure results from calculating the HQs based on the NOAEL and LOAEL (HQ_N and HQ_L, respectively) for terrestrial and aquatic avian and mammalian species are discussed below.

4.4.1 Benthic Invertebrates / Plants

Two COPCs, Ba and Sr, associated with the sediment of the San Juan River were determined to have high enough concentrations in the sediment to have EQ_{max} values in excess of 1.0 (Table 16). In addition EQ_{max} values could not be calculated for Be due to the lack of an available TRV (Table 16). The measured concentrations at each SJR location identified barium and strontium as having the potential for risk to benthic invertebrates (Table 10).

4.4.2 Aquatic Water-Column Communities Including Fish

Fourteen constituents associated with the surfaced water of the San Juan River were determined to have maximum concentrations in the surface water that resulted in EQ_{max} values above 1.0 (Table 17). For many of the surface water COPCs, the maximum concentration was detected at the Colorado border (4954000) including Al, Ba, Be, Co, Cu, Fe, Pb, Mn, Hg, NO_3^-, NO_2^- as N, Ag, and V (Table 7).

4.4.3 Avian Aquatic Species

Mallard

Three COPCs including Al, Ba, and Zn, pose a potential risk to the mallard due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al and Ba.

Belted Kingfisher

Four COPCs including Al, Ba, Pb, and Zn pose a potential risk to the belted kingfisher due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al and Ba.

Great Blue Heron

Four COPCs including Al, Ba, Pb, and Zn pose a potential risk to the great blue heron due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al and Ba.

The avian aquatic risks from four COPCs were not able to be evaluated due to the lack of TRVs for Be, Fe, NO_3^-,NO_2^- as N, and Sr.

4.4.4 Mammalian Aquatic Species

Raccoon

Four COPCs including Al, Ba, V, and Zn pose a potential risk to the raccoon due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al, Ba, and V.

Muskrat

Three COPCs including Al, Ba, and V pose a potential risk to the muskrat due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al, Ba, and V.

Mink

Six COPCs including Al, Ba, Co, Cu, V, and Zn pose a potential risk to the mink due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al, Ba, and V.

The mammalian aquatic risks from Fe were not able to be evaluated due to the lack of TRVs.

4.4.5 Amphibian Aquatic Species

Bullfrog

Six COPCs including Al, Ba, Pb, Hg, V, and Zn pose a potential risk to the bullfrog due to HQ_N's greater than 1.0 (Table 18). Calculated HQ_L's were greater than 1.0 for Al, Ba, Hg, V, and Zn.

The aquatic amphibian risks from four COPCs were not able to be evaluated due to the lack of TRVs including Be, Fe, NO_3^-, NO_2^- as N, and Sr.

4.5 Summary of Step 2 Ecological Risk Screening

Using the maximum concentration at any sampling location for the SJR as a whole, Table 19 summarizes results of the post-GKM spill Step 2 screening for COPCs present in the study area. All upper trophic level ROCs are retained as having potential risk due to at least one receptor (lower or upper-trophic) at the conclusion of this step in the ERA process. Fourteen COPCs were retained in Step 2 and summarized in Table 19.

Pre-GKM Spill Evaluation

Step 2 risks to ROCs were also evaluated using the maximum concentration measured prior to the GKM spill plume entering Utah in the SJR. The Step 2 benthic invertebrate/aquatic plant evaluation resulted in Ba showing potential risk ($EQ_{max} > 1.0$) and Be, Sr, and Tl being moved to the Uncertainties section (Section 5) because of the lack of TRVs (Be and Tl) or the lack of available concentration data (Sr) (Table 10). The Step 2 aquatic water column communities evaluation (including fish) indicated potential risk ($EQ_{max} > 1.0$) for Al, Ba, Cu, Fe, Pb, Mn, Ag, and Zn; while risks were uncertain due to the lack of measured concentrations for Be, Co, Hg, NO_3^-,NO_2^- as N, Sr, and V (Table 7). The pre-GKM spill evaluation of upper-trophic level ROCs indicated HQ_n greater than 1.0 for all ROCs for at least one COPC (Table 20). Below is a list of the COPCs identified as posing potential risk ($HQ_N > 1.0$) for the identified ROC:

- Belted Kingfisher - Al, Ba, Pb, Zn
- Great Blue Heron – Al, Ba, Pb, Zn
- Mink - Al, Ba, Co, V, Zn
- Muskrat – Al, Ba, V
- Raccoon - Al, Ba, V, Zn
- Bullfrog – Al, Ba, Pb, Hg, V, Zn

Comparing the pre-GKM spill and the post-GKM spill surface water concentrations indicated that only Fe and Mn were in excess of the ESV in pre-GKM spill surface water, but additional constituents including Al, Ba, Be, Ca, Cu, Pb, Hg, Mg, NO_3^-,NO_2^- as N, Ag, Sr, V, and Zn (Table 7) were elevated in post-GKM spill surface water. Pre-GKM spill sediment indicated only Ba was in excess of ESV, while Ba and Sr were in excess of ESVs for post-GKM spill sediments (Table 10). Therefore, direct toxicity risk to aquatic communities including fish as well as benthic invertebrates and aquatic plants was increased in the post-GKM spill surface water and sediments due to the increased number of constituents in excess of ESVs and magnitude of these exceedances.

The risk to upper-trophic level ROCs were also compared for the pre-GKM spill and the post-GKM spill sediment and surface water concentrations. Pre-GKM spill analysis identified the same ROC and constituent combinations as the Post-GKM spill analysis with respect to HQ_N greater than 1.0. Therefore, the GKM spill did not increase the number of constituents that pose potential risk to upper trophic level ROCs. Pre-GKM spill concentrations of Al, Pb, V, and Zn indicated an increased HQ_N, indicating a higher ratio of calculated ROC dosage to literature-based TRV, or a higher risk potential, than post-spill GKM concentrations. The calculated risk potential (HQ_N) for Ba, Co, Cu, and Hg were higher in post-spill GKM then in pre-spill GKM.

Individual Sampling Locations Post-GKM Spill Evaluation

The benthic invertebrate/aquatic plant evaluation indicated potential risk for Ba and Sr (at all locations), while Be and Tl were retained as uncertainties due to the lack of ESVs (Table 10). The evaluation of the potential risk of surface water concentrations on aquatic water column communities resulted in the following:

- 12 COPCs retained at 4954000 (SJR @ US 160 xing in CO);
- 10 COPCs retained at 4953990 (SJR @ Town of Montezuma);
- 9 COPCs retained at 4953880 (SJR @ McElmo Wash);
- 8 COPCs retained at 4953250 (SJR @ Sand Island);
- 8 COPCs retained at 4953000 (SJR @ Mexican Hat US 163 xing); and
- 5 COPCs retained at 4952942 (SJR @ Clay Hills) (Table 7).

Step 2 upper-trophic level food web modeling resulted in HQ_N greater than 1.0 for up to nine COPCs (to at least one receptor) at Location #4954000 to five COPCs at Location #4952942 (Tables 21 – 25). For the most part, when the HQ_N was in excess of 1.0, the HQ_L was also in excess of 1.0. The number of COPCs with potential risk to ROC decreased with the distance downstream on the SJR from the Colorado-Utah border to Lake Powell.

4.6 Scientific Management Decision Point I

The results indicate that COPCs pose potential risks to aquatic-dependent ROCs based on conservative exposure assumptions. A review of the study-area data that were used as the basis for calculating Step 2 risks suggests that there are sufficient data collected and that data were of sufficient quality to evaluate Step 2 risks to ROCs in the relevant media present in the study area (sediment and surface water). Thus, there do not appear to be any significant data gaps present at this stage of the ERA. Given the potential risks calculated in the Step 2 ERA, it would be appropriate to advance to Step 3 of the ERA framework to address several uncertainties and conservative assumptions as discussed in the next section. Step 3 of the ERA framework would encompass a modification to Step 2 which would incorporate much more realistic exposure factors including mean surface water or sediment concentration as well as mean FIR, and WIR. Risk potential would also be evaluated on the calculation of both HQ_N and HQ_L, because the LOAEL is the value that indicates effects.

5 UNCERTAINTY ASSOCIATED WITH THE STEP 2 ERA

Uncertainties are present in all risk assessments because of the limitations of the available data and the need to make assumptions and extrapolations based upon incomplete information. The main factors contributing to uncertainty in this SLERA are discussed in the following subsections.

5.1 Ecological Screening Values

Constituents without available ESVs for a medium were eliminated as a COPC in Step 1 of the assessment, but represent an uncertainty in the SLERA. In this case, the contaminant cannot be ruled out as a potential contributor of ecological risk because it could be present at levels that are toxic to ecological communities. It is possible that these constituents may contribute some additional risk to the SJR. Sulfate was the only surface water constituent that was moved to the Uncertainty section due to the lack of an ESV, while sediment ESVs were lacking for Be, Ca, Mg, K, NA, and Tl.

5.2 NOAEL vs. LOAEL Hazard Quotients

The calculation of hazard quotients for upper trophic level receptors in Step 2 is based on a comparison of the maximum COPC dosage with a literature-based NOAEL. The literature-based NOAEL is established from laboratory tests in which a concentration series is used to establish a toxicity gradient. The NOAEL is the highest tested concentration that does not illicit a toxic response, while the LOAEL is the lowest tested concentration that elicits a toxic response. The gradient on which the concentration series is based could affect the accuracy of risk conclusions, particularly if the NOAEL and LOAEL are considerably different values. The use of the NOAEL in Step 2 to calculate HQs would over-estimate the risk potential as indicated by the fact that based on LOAELs; several receptors/inorganic combinations do not exhibit potential risk in the Step 2 analysis.

5.3 Habitat Usage Factor

The habitat usage factor used in Step 2 analysis was 1.0, indicating that ROCs use only the study area or the stream segment for the station by station analysis for foraging. When examining the entire SJR from the Colorado-Utah border to Lake Powell this may be a reasonable assumption, but when looking at smaller delineated units of the SJR (i.e., stream segments between sampling stations) this may be overly conservative for some of the ROC. For some upper-trophic level ROCs (e.g., great blue heron), the smaller study areas may only make up a fraction of their foraging area and therefore using a habitat usage factor of 1.0 will over-estimate the risk to these receptors.

5.4 Maximum Exposure Concentrations

Maximum sediment and surface water concentrations were used to calculate the hazard quotients in Step 2 of the risk assessment. The use of maximum sediment and surface water concentrations indicate that upper trophic level ROCs are only exposed to the maximum concentration, when in fact the ROCs would be exposed to the gradient of COPC concentrations established at the study area. The use of maximum concentrations in Step 2 risk analyses over-estimates the risk to ROCs. The use of average or median inorganic concentrations would be more realistic with respect to the ROCs and is typically completed in Step 3 of the ERA framework.

5.5 Most Contaminated Dietary Item

Risks to upper-trophic level ROCs were calculated in Step 2 by using the dietary item with the highest modeled concentration to represent 100 percent of the ROC's diet. The upper trophic level ROCs used in the SLERA have variable diets that may consist of plants, invertebrates, or fish. By only using the dietary item with the highest concentration, the calculated HQ over-estimates the risk potential to upper-trophic level ROCs.

5.6 Dry-Weight vs. Wet-Weight Intake

Step 2 upper-trophic level dosages of COPCs were calculated using dry weight sediment concentrations, which were then used to derive dry weight dietary item (e.g., invertebrate, plant, and fish) concentrations. However, these dietary items are not consumed by ROCs as dry weight, but rather on a wet weight basis. The concentrations of COPCs derived for invertebrates, plants, and fish in the study area on a dry weight basis would thus be higher than that actually consumed by ROCs.

Therefore, food web modeling in Step 2, using dry weight COPC concentrations, will overestimate the risk to ROCs. Further evaluation of the potential uncertainty surrounding the use of dry weight would be completed in Step 3 under the ERA framework.

5.7 Ingestion TRVs

Data on the toxicity of COPCs to the receptor species were sparse or lacking, requiring the use of data from other wildlife species or from laboratory studies with non-wildlife species. Use of other wildlife or laboratory species is standard for ERAs because so few wildlife species have been tested directly for most constituents. The uncertainties associated with applying NOAELs and LOAELs from other species were minimized through the selection of the most appropriate test species for which suitable toxicity data were available. It is not known whether the wildlife or laboratory species are more or less sensitive to COPCs than the ROCs that are likely to occur in the study area. This uncertainty could either over- or under-estimate the risk to the ROCs.

5.8 Food Web Exposure Modeling

Constituent concentrations in aquatic food items (plants, benthic invertebrates, and fish) were modeled from measured media concentrations and were not directly measured. The use of generic, literature-derived exposure models and accumulation formulae introduces uncertainty into the resulting estimates. The values selected and methodology employed was intended to provide a conservative estimate of potential food web exposure concentrations in this SLERA. Another source of uncertainty is the use of default assumptions for exposure parameters such as BCFs and BAFs. Although BCFs or BAFs for many bioaccumulative chemicals were readily available from the literature and were used in the ERA, the use of a default factor of 1.0 for COPCs lacking BCFs or BAFs is a source of uncertainty.

5.9 Acute versus Chronic Exposure

Constituent concentrations associated with the GKM spill may have only been in the surface water column of the SJR for a short period of time. This would limit the amount of uptake that was modeled in the food web model or the exposure of aquatic communities including fish to these constituents. TRVs were based on chronic exposure and chronic endpoints (i.e., reproduction, development) and their use may overestimate the risk associated with surface water concentrations of the GKM spill.

Inorganics, like the constituents associated with the GKM-spill, tend to sorb to sediments and may persist in the sediment for longer periods of time. Therefore, the use of TRVs based on chronic exposure is representative of the ROC exposure.

The uncertainties discussed in this section affect the estimated potential risks as presented in the SLERA, and should be considered when evaluating the results of the assessment. The next step in the ERA process, Step 3, would evaluate ways to address and refine the assumptions required in the SLERA to provide more refined estimates of potential risks to upper-trophic level ROCs in the study area.

6 ECOLOGICAL RISK SUMMARY

A screening level ecological risk assessment was performed for COPCs in sediment and surface water in the San Juan River associated with the Gold King Mine spill. The results of Step 1 identified multiple inorganic constituents as COPCs in both sediment and surface water and Step 2 indicated a potential for risk to certain types of receptors that are likely present in the study area. The identification of inorganics as COPCs and the identification of ROCs potentially at risk supports a decision to conduct additional steps of the ERA process to provide more realistic estimates of exposure and risk, consistent with USEPA guidance (USEPA 1997a).

Standard ERA practice (USEPA 1997a) places ecological risk in the context of assessment and measurement endpoints, where assessment endpoints are those characteristics of an environment that need to be protected and measurement endpoints provide distinct measures of this degree of protection. The results of the Step 2 ERA are shown in Table 26 in the context of the defined assessment and measurement endpoints. These results suggest the possibility of risk from COPCs in certain media and for certain guilds of receptors. The results of the SLERA are summarized below for sediment and surface water across the SJR study area for pre-spill and post-spill maximum concentrations; and for post-spill maximum concentrations at each sampling location on the SJR.

6.1 Post GKM Spill Sediment and Surface Water

6.1.1 Step 1 for Sediment and Surface Water

Post GKM spill analysis of maximum measured surface water and sediment concentrations in the entire Utah portion of the SJR and Lake Powell, resulted in fourteen constituents being retained and further evaluated in Step 2 and seven being moved to the Uncertainty section due to the maximum detection limit being in excess of the ESV or the lack of an ESV. In sediment, Ba and Sr, were the only two COPCs with detected maximum concentration in excess of ESVs; while seven additional COPCs were moved to the Uncertainty section due to either being not detected and the detection level being in excess of the ESV (antimony) or lacking an ESV or essential nutrient (Be, Ca, K, Mg, Na, and Tl). In surface water, fourteen COPCs were identified as having maximum detected concentration in excess of ESVs (Table 11); while one additional COPCs (SO_4^-) lacked an ESV.

6.1.2 Step 2 for Sediment and Surface Water

All COPCs identified in Step 1 were retained in Step 2 due to at least one receptor (lower or upper trophic level) indicating potential risk. Therefore, all fourteen COPCs evaluated in Step 2 indicate risk and should be further evaluated (Table 18).

6.2 Pre-Spill Sediment and Surface Water

6.2.1 Step 1 for Sediment and Surface Water

Based on the sediment and surface water maximum concentrations available for the SJR before the GKM spill entered Utah, sediment concentrations of Ba (Table 10) and surface water concentrations of Fe and Mn (Table 7) were greater than the ESVs. Sediment ESVs were lacking for essential nutrients (i.e., Ca, Mg, K, and Na), as well as Be and Tl and these COPCs were identified as uncertainties. Certain inorganics including sediment concentrations of strontium and surface water concentrations of Sb, Be, Cd, Ca, Cl-, Co, Mo, NO_3^-,NO_2^- as N, Na, Sr, Tl, and V were not measured in the SJR prior to the spill thus pre-spill risks due to these COPCs could not be quantified.

6.2.2 Step 2 for Sediment and Surface Water

Using the full list of COPCs identified in the post-spill GKM, pre-spill concentrations of these COPCs were evaluated in Step 2 (Table 20). Based on this analysis of pre-spill conditions, similar results as the post-GKM spill were observed. The Step 2 upper trophic level risk assessment indicated that Ag would be the only COPC not recommended for further evaluation as all HQ_N's were less than 1.0.

6.3 Evaluation of Post-Spill Conditions at Each Sampling Station

6.3.1 Step 1 for Sediment and Surface Water

The evaluation of risk was also conducted on the maximum surface water and sediment concentration from each sampling location across the SJR and LP. For surface water, Ca, Fe, Mg, Mn, Sr, and Zn were only identified at one location as being in excess of the ESVs. All other sampling locations had maximum concentrations that were less than ESVs. Al, Ba, Be, Co, Pb, Hg, NO_3^-,NO_2^- as N, Ag, and V were identified at multiple locations as having maximum concentration in excess of ESVs. For the evaluation of sediment, only Ba and Sr were identified as COPCs and all sampling locations had maximum concentration in excess of ESVs.

6.3.2 Step 2 for Sediment and Surface Water

As was completed for the pre-spill evaluation, post-spill COPCs identified using the maximum surface water or sediment concentration were evaluated at each sampling location using the maximum surface water or sediment concentration. Step 2 upper-trophic level food web modeling resulted in HQ_n greater than 1.0 for up to nine COPCs (to at least one receptor) at Location #4954000 to five COPCs at Location #4952942 (Tables 21 – 25). The number of COPCs retained decreased with the distance downstream on the SJR from the Colorado-Utah border to Lake Powell.

7 RECOMMENDATIONS

Steps 1 and 2 of the ERA process intentionally use simplistic and conservative literature-based accumulation models to evaluate upper-trophic level organism risk. The use of the maximum observed concentration in a medium (e.g., sediment and surface water), low ROC body weight, high ROC ingestion rates, most contaminated dietary item in dosage calculations, and a habitat-usage factor of 1.0 all result in likely over-estimates of bioaccumulation factors for inorganics in this study area, therefore overestimating the risk (HQ) calculations for many of the upper trophic level species. Based on the potential risk to the upper trophic level organisms, a modified BERA (Phase I) including Step 3 EPA Framework is recommended for the study area. The modified BERA will remove some of the conservative bias in the risk estimates by using median or average values for those variables that are driving the risk, including media concentration of inorganics and food web variables (i.e., body weight, ingestion rate, area use factor, etc.). Further steps of the EPA Framework including Step 3 would evaluate the extent of bioaccumulation of metals by analyses of tissue concentrations in ROC diet items (such as fish and aquatic invertebrates in the study area would provide a more accurate estimate of exposure and potential risk to upper-trophic level ROCs (Phase II BERA).

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FIGURES

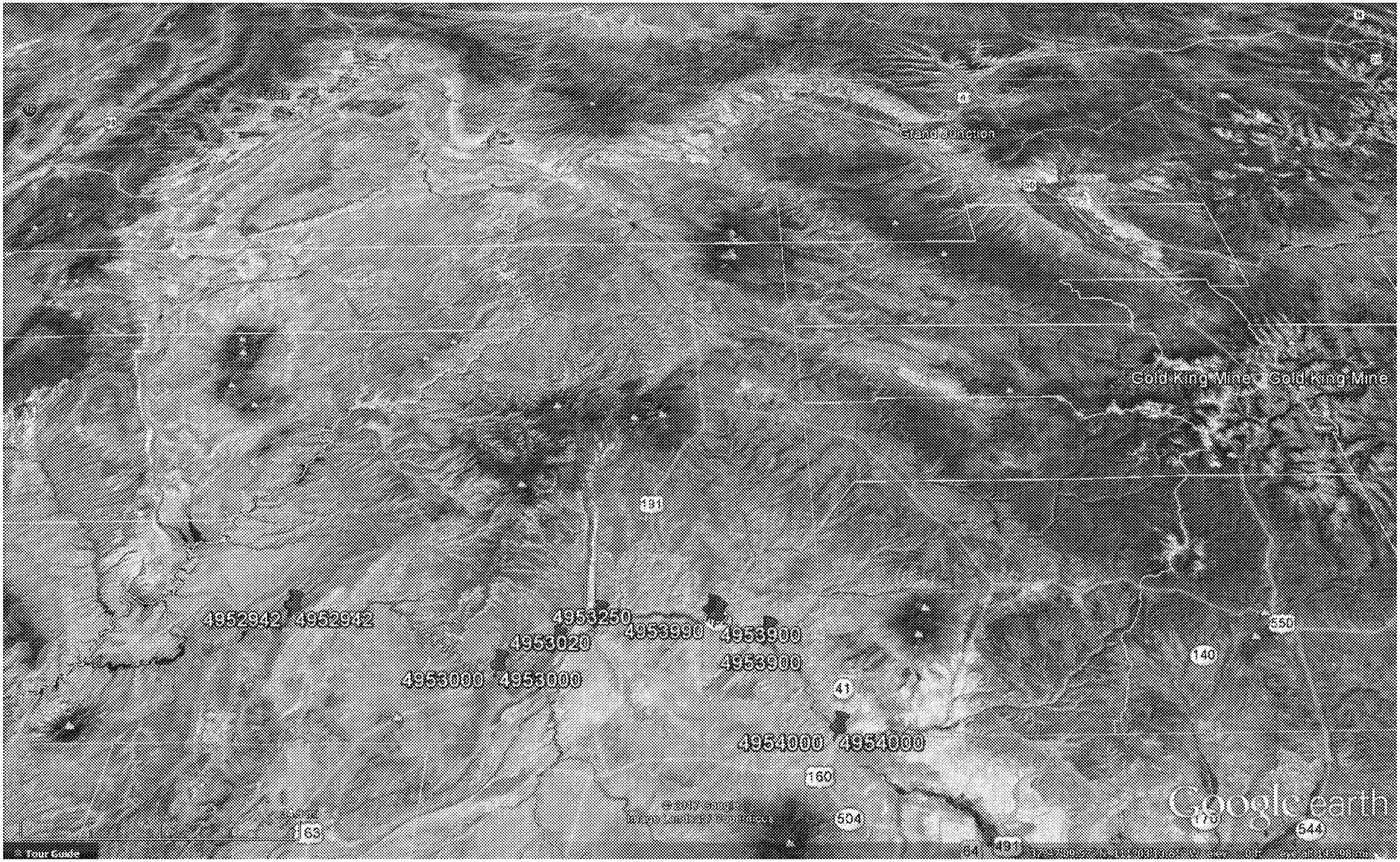


Figure 1. Map of study area with sampling locations.

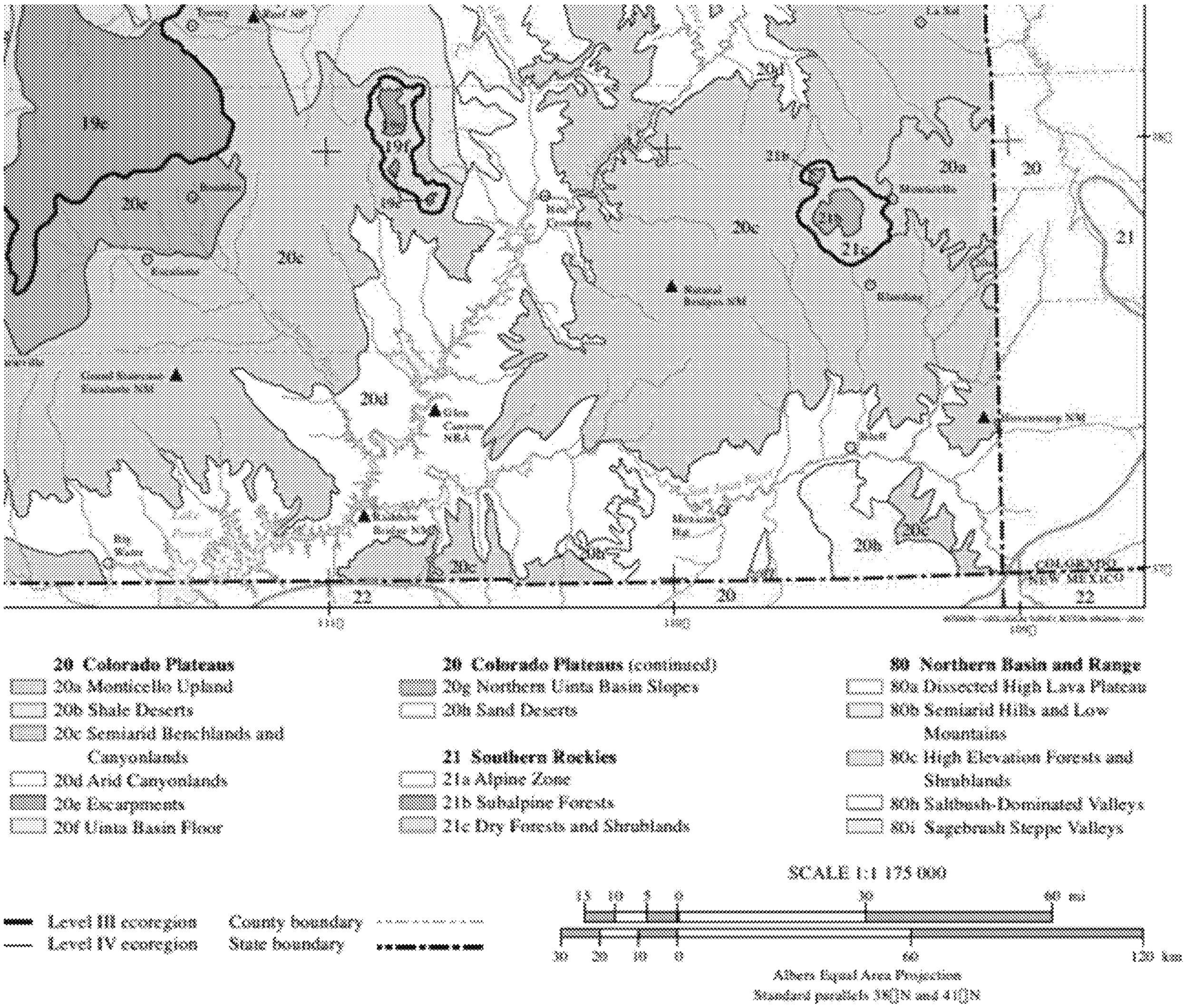
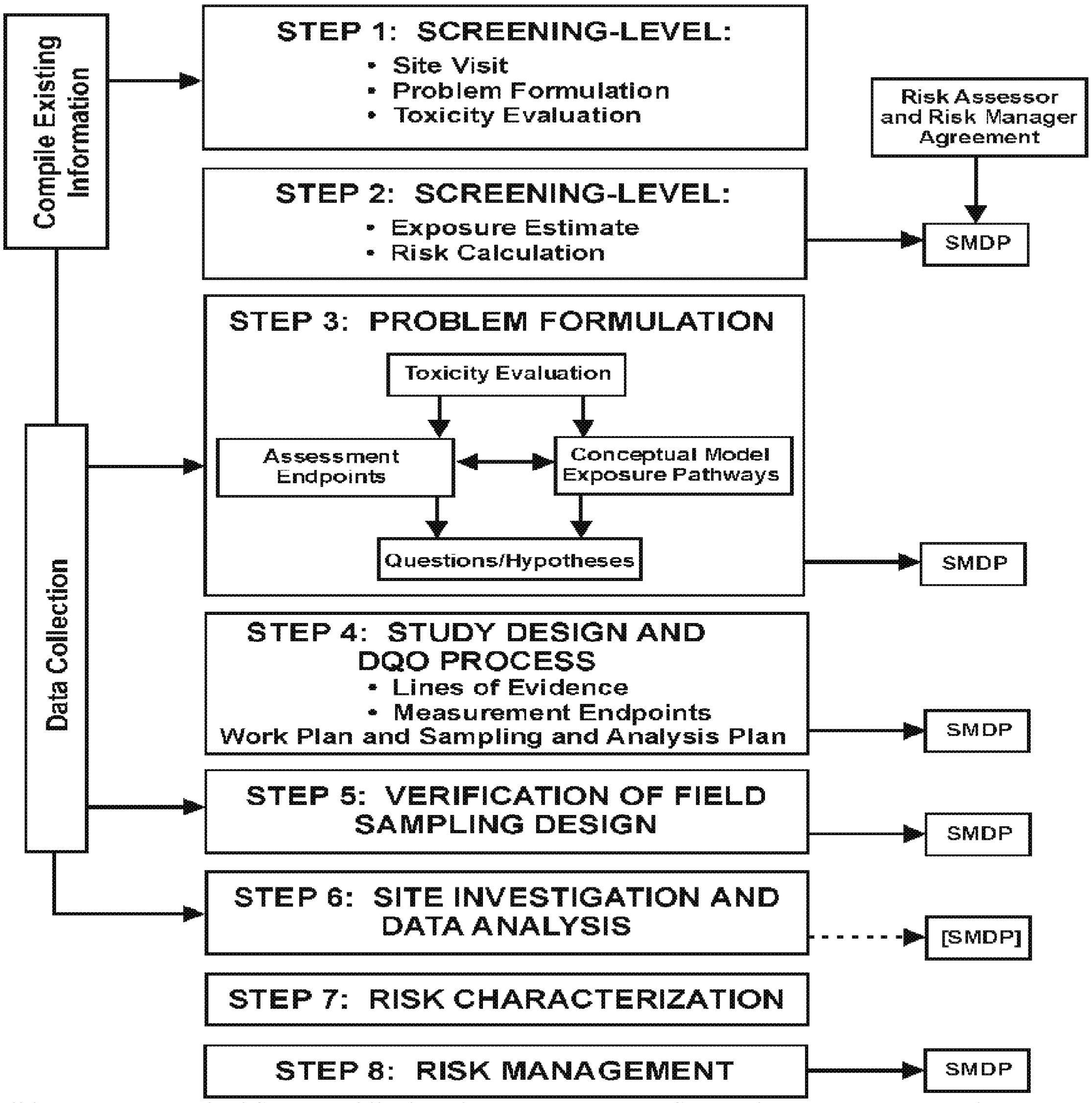


Figure 2. Map of Utah Ecoregions in the SJR study vicinity. Source: Woods et al., 2001.



Solid arrows are required SMDP, while dotted arrows represent a SMDP that may or may not always occur in the ERA process

Figure 3. The EPA Eight-Step Ecological Risk Assessment Process.

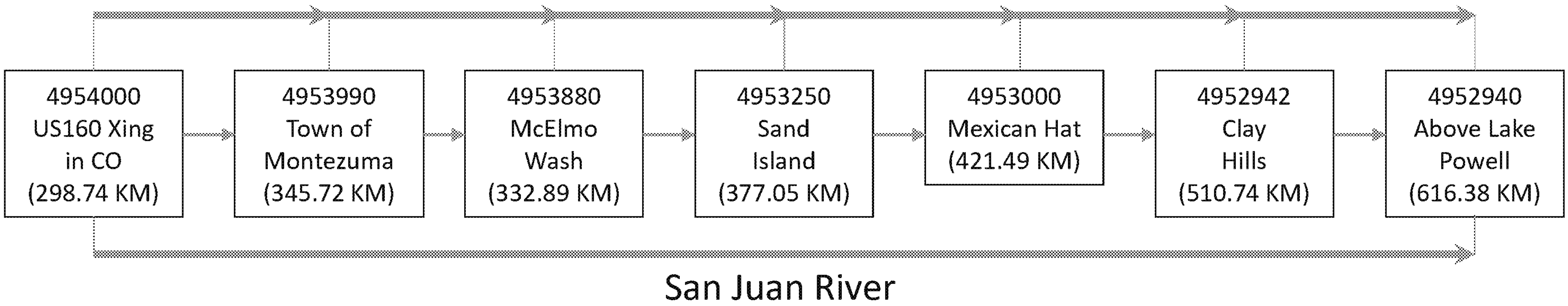


Figure 4. Illustration of the San Juan River in Utah. Sample location 4954000 is at the eastern border with Colorado and the San Juan River flows west toward Lake Powell (4952940).

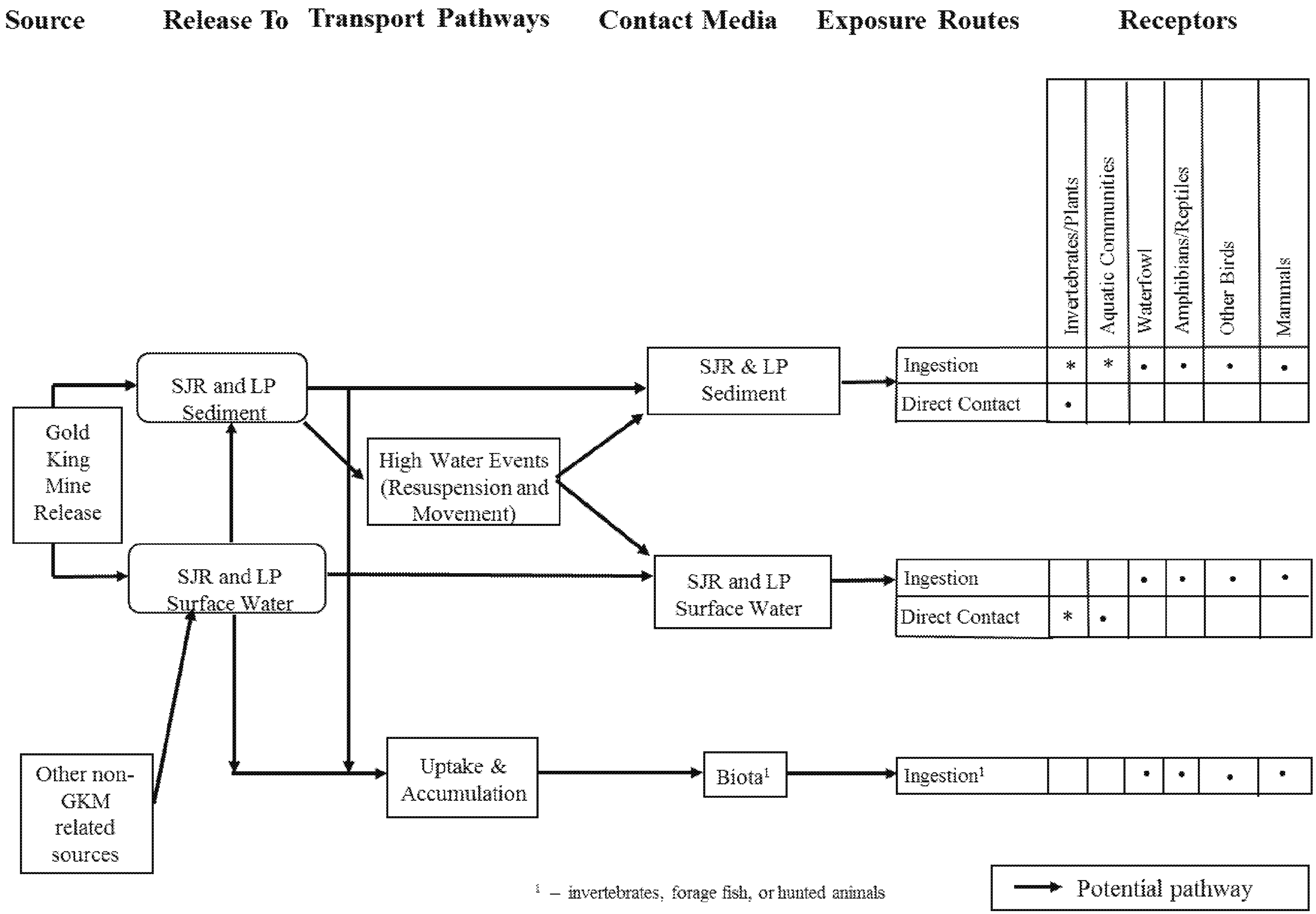


Figure 5. Conceptual Site Model for Ecological Risk Assessment.

TABLES

Table 1. List of threatened and endangered species known or expected to be on or near the project area.

Common Name	Scientific Name	Status
Mammals		
Black-footed Ferret	*Mustela nigripes*	Endangered
Gray Wolf	*Canis lupus*	Endangered
Grizzly Bear	*Ursus arctos pruinosus*	Endangered
New Mexico Meadow Jumping Mouse	*Zapus hudsonius luteus*	Endangered
North American Wolverine	*Gulo gulo luscus*	Proposed Threatened
Utah Prairie Dog	*Cynomys parvidens*	Threatened
Birds		
California Condor	*Gymnogyps californianus*	Endangered
Gunnison Sage-grouse	*Centrocercus minimus*	Threatened
Mexican Spotted Owl	*Strix occidentalis lucida*	Threatened
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	Endangered
Yellow-billed Cuckoo	*Coccyzus americanus*	Threatened
Reptiles		
Northern Mexican Gartersnake	*Thamnophis eques megalops*	Threatened
Fishes		
Bonytail Chub	*Gila elegans*	Endangered
Colorado Pikeminnow (squawfish)	*Ptychocheilus lucius*	Endangered
Greenback Cutthroat Trout	*Oncorynchus clarki stomias*	Threatened
Humpback Chub	*Gila cypha*	Endangered
Razorback Sucker	*Xyrauchen texanus*	Endangered
Roundtail Chub	*Gila robusta*	Proposed threatened
Zuni Bluehead Sucker	*Catostomus discobolus yarrowi*	Endangered
Flowering Plants		
Jones Cycladenia	*Cycladenia humils var. jonesii*	Threatened
Mesa Verde Cactus	*Sclerocactus mesae-verdae*	Threatened
Navajo Sedge	*Carex specuicola*	Threatened
Siler Pincushion Cactus	*Pediocactus sileri*	Threatened
Welsh's Milkweed	*Asclepias welshii*	Threatened

Table 2. Land Cover/Land Use for San Juan County.

Land Cover/Land Use	**Acres**	**Percent of Total**
Shrub/Rangelands	2,937,699	58
Forest	1,890,662	38
Grain Crops	55,117	1
Water	45,629	1
Conservation Reserve Program (CRP)[a]	36,079	1
Grass/Pasture/Hay lands	26,733	1
Row Crops	26,557	1
Developed Land	4,488	<0.1%
Orchards/Vineyards	71	<0.01%
Total[b]	5,023,035	100

a: Estimate from Farm Service Agency records and include CRP/CREP (Conservation Reserve Enhancement Program)
b: Totals may not add due to rounding and small unknown acreages

Table 3. Estimated mass of metals delivered to the Animas River from the Gold King mine release (USEPA 2017).

Metal	Total (kg)	Dissolved (kg)	Collodial/Particulate (kg)
Aluminum	41,132	6,376	34,755
Antimony	14.2	0.173	14.0
Arsenic	358.4	2.9	355.4
Barium	417.6	2.2	415.4
Beryllium	6.0	2.4	3.6
Cadmium	7.7	7.0	0.7
Calcium	30,484	30,345	139
Chromium	30.6	0.38	30.2
Cobalt	17.7	14	3.7
Copper	1,615	731	884
Iron	433,086	3,750	429,335
Lead	7,658	11.2	7,647
Magnesium	15,891	2,490	13,401
Manganese	3,599	2,581	1,018
Mercury	0.8	0.0001	0.8
Molybdenum	86.8	0.4	86.4
Nickel	12.5	6	6.2
Potassium	11,854	426	11,428
Selenium	11.2	0.4	10.8
Silver	47.4	0.2	47.3
Sodium	1427.4	290	1,137.1
Thallium	5.6	0.2	5.4
Vanadium	237.8	0.8	237.0
Zinc	2,059	1,904	155
Total Metals	550,060	48,942	501,118
Major Cations	59,656	33,551	26,106
Total Minus Cations	490,404	15,391	475,012
Sulfate	18,170	NA	NA
Chloride	13,63	NA	NA
Fluoride	114.0	NA	NA
Nitrate as N	0.28	NA	NA

Table 4. Ecological Risk Screening Assessment Endpoints.

Assessment Endpoint	Null Hypothesis	Measurement Endpoint	Specifics of Assessment
Ecological health of aquatic water column communities	Surface water does not exhibit a detrimental effect on aquatic plant and organism survival and growth	Evaluation of surface water chemistry with respect to water quality criteria	• Comparison of surface water concentrations to water quality criteria.
Ecological health of benthic invertebrate communities	Sediment does not exhibit a detrimental effect on invertebrate survival and growth	Evaluation of sediment chemistry with respect to sediment screening values	• Comparison of sediment concentrations to sediment screening values.
Long term health and reproductive capacity of omnivorous aquatic avian species (mallard duck)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Vegetation and invertebrate dose approximated by multiplying sediment and surface water concentration by BCF or BAF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.
Long term health and reproductive capacity of piscivorous aquatic avian species (blue heron)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Food dose approximated by multiplying sediment and surface water concentration by BCF or BAF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.
Long term health and reproductive capacity of piscivorous aquatic avian species (belted kingfisher)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Food dose approximated by multiplying sediment and surface water concentration by BCF or BAF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.
Long term health and reproductive capacity of omnivorous aquatic mammalian species (raccoon)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Dose from food approximated by multiplying sediment and surface water concentration by BAF or BCF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.

Table 4. Continued.

Assessment Endpoint	Null Hypothesis	Measurement Endpoint	Specifics of Assessment
Long term health and reproductive capacity of herbivorous aquatic rodent species (muskrat)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Dose from food approximated by multiplying sediment and surface water concentration by BAF or BCF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.
Long term health and reproductive capacity of piscivorous aquatic mammal species (mink)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Dose from food approximated by multiplying sediment and surface water concentration by BAF or BCF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.
Long term health and reproductive capacity of omnivorous aquatic amphibian species (bullfrog)	Ingestion of COPC in prey does not have a negative impact on growth, survival, and reproductive success of the species	Evaluation of dose in prey based on sediment data and dietary exposure models	• Dose from food approximated by multiplying sediment and surface water concentration by BAF or BCF for COPC. • The risk associated with the calculated dose will be evaluated by comparison to TRVs.

Notes:
BCF – Bioconcentration Factor
BAF – Bioaccumulation Factor
COPC – Constituent of Potential Concern
TRV – Toxicity Reference Value

Table 5. Summary of surface water ecological screening values. Hardness dependent values were calculated at the lowest hardness recorded for the day at the sampling location where the maximum constituent concentration was detected.

Constituent	Ecological Screening Values (ESVs)	Units	Source
Aluminum, Dissolved	87.00	µg/L	Utah 2017
Antimony, Dissolved	30.00	µg/L	Suter and Tsao 1996
Arsenic, Dissolved	150.00	µg/L	Utah 2017
Barium, Dissolved	4.00	µg/L	Suter and Tsao 1996
Beryllium, Dissolved	0.66	µg/L	Suter and Tsao 1996
Cadmium, Dissolved[1]	1.31	µg/L	Utah 2017
Calcium, Dissolved	116	mg/L	Suter and Tsao 1996
Chloride	230	mg/L	USEPA 2017
Chromium, Dissolved[2]	128.79	µg/L	Utah 2017
Cobalt, Dissolved	23.00	µg/L	Suter and Tsao 1996
Copper, Dissolved[2]	20.68	µg/L	Utah 2017
Iron, Dissolved	1	mg/L	USEPA 2017
Lead, Dissolved[2]	1.99	µg/L	Utah 2017
Magnesium, Dissolved	82	mg/L	Suter and Tsao 1996
Manganese, Dissolved	120.00	µg/L	Suter and Tsao 1996
Mercury, Dissolved	0.012	µg/L	Utah 2017
Molybdenum, Dissolved	240.00	µg/L	USEPA 1996
Nickel, Dissolved[2]	88.98	µg/L	Utah 2017
Nitrate-Nitrite-Nitrogen, Total	4.00	mg/L	Utah 2017
Potassium, Dissolved	53	mg/L	Suter and Tsao 1996
Selenium, Dissolved	4.60	µg/L	Utah 2017
Silver, Dissolved[3]	0.04	µg/L	Utah 2017
Sodium, Dissolved	680	mg/L	Suter and Tsao 1996
Strontium, Dissolved	1.5	mg/L	Suter and Tsao 1996
Sulfate, Total	NA	µg/L	None
Thallium, Dissolved	0.80	µg/L	CCME 1999
Vanadium, Dissolved	20.00	µg/L	Suter and Tsao 1996
Zinc, Dissolved[2]	180.33	µg/L	Utah 2017

Notes:
µg/L = Microgram per liter
NA = not available
[1] – 162 mg/L as $CaCO_3$ was the lowest hardness measured or calculated on the same day (8/27/15) at the location (#4953990) of the maximum detected concentration.
[2] – 190 mg/L as $CaCO_3$ was the lowest hardness measured or calculated on the same day (8/28/15) at the location (#4954000) of the maximum detected concentration.
[3] – 104.2 mg/L as $CaCO_3$ was the lowest hardness measured or calculated on the closest day (6/25/16) at the location (#4954000) of the maximum detected concentration.

Table 6. Summary of surface water COPCs for the San Juan River based on the maximum concentration for all seven sampling locations.

Analyte	Frequency of Detection (1)	Units	Range of Sample Quantitation Limits (SQLs)				Range of Post Spill Detections				Location (Sample ID) of Maximum Detected Concentration	Concentration Used for Screening (2)	Ecological Screening Value		Maximum Ratio of Max Value Compared to Screening Value	Ration Greater than 1.0?	Contaminant Category (3)
			Min.	Q	Max	Q	Min.	Q	Max	Q			Value	Ref.			
aluminum dissolved	185/246	µg/L	10	U	100	U	10	J	20700		4954000	20700	87	a	237.93	Y	A
antimony dissolved	121/246	µg/L	2	U	3	U	0.0516	J	3.458	-	4953990	3.458	30	b	0.12	N	--
arsenic dissolved	135/246	µg/L	1	U	2	U	0.628	J	5.55	-	4954000	5.55	150	a	0.04	N	--
barium dissolved	140/247	µg/L	100	U	100	U	42.9		451		4954000	451	4	b	112.75	Y	A
beryllium dissolved	58/246	µg/L	1	U	2	U	0.0299	J	1.58	J	4954000	1.58	0.66	b	2.39	Y	A
cadmium dissolved	16/246	µg/L	0.1	U	0.5	U	0.1	J	0.303	J	4953990	0.303	1.31	a	0.23	N	--
calcium dissolved	246/246	mg/L	--	--	--	--	30.8		272		4953880	272	116	b	2.34	Y	A
chloride total	241/241	mg/L	--	--	--	--	3.63		55.6		4953880	55.6	230	c	0.24	N	--
chromium dissolved	16/246	µg/L	2	U	2	U	2		12		4954000	12	128.79	a	0.09	N	--
cobalt dissolved	117/246	µg/L	4	U	30	U	0.0455	J	30	U	4953990	30	23	b	1.30	Y	A
copper dissolved	209/246	µg/L	0.02	U	1	U	1		27.7	B	4954000	27.7	20.68	a	1.34	Y	A
iron dissolved	101/246	mg/L	0.0001	U	0.02	U	0.02		16.7		4954000	16.7	1	c	16.70	Y	A
lead dissolved	94/246	µg/L	0.1	U	2	U	0.1		15.7		4954000	15.7	1.99	a	7.89	Y	A
magnesium dissolved	246/246	mg/L	--	--	--	--	4.98		181		4953880	181	82	b	2.21	Y	A
manganese dissolved	126/246	µg/L	2	U	5	U	1.55	J	413		4954000	413	120	b	3.44	Y	A
mercury dissolved	17/246	µg/L	0.00015	U	0.2	U	0.01	J	0.2	J	4954000	0.2	0.012	a	16.67	Y	A
molybdenum dissolved	220/243	µg/L	0.002	U	1	U	1		5.87		4953000	5.87	240	d	0.02	N	--
nickel dissolved	69/246	µg/L	0.002	U	5	U	0.756	J	12.7		4954000	12.7	88.98	a	0.14	N	--
nitrate-nitrite-nitrogen total	208/241	mg/L	0.01	U	0.1	U	0.0125		46.4		4954000	46.4	4	a	11.60	Y	A
potassium dissolved	246/246	mg/L	--	--	--	--	1.59		7.89		4954000	7.89	53	b	0.15	N	--
selenium dissolved	147/246	µg/L	1	U	2	U	0.504	J	2.97		4953000	2.97	4.6	a	0.65	N	--
silver dissolved	88/178	µg/L	0.5	U	2	U	0.0249	J	0.5	U	4954000	0.5	0.04	a	12.50	Y	A
sodium dissolved	246/246	mg/L	--	--	--	--	0.0534		225		4953880	225	680	b	0.33	N	--
sulfate, total	241/241	mg/L	--	--	--	--	45		1570		4953880	1570	--	--	--	Y	C
strontium dissolved	138/138	mg/L	--	--	--	--	0.251		4.57		4953880	4.57	1.5	b	3.05	Y	A
thallium dissolved	41/243	µg/L	0.002	U	0.1	U	0.025	J	0.282		4953000	0.282	0.8	f	0.35	N	--
vanadium dissolved	120/243	µg/L	0.005	U	30	U	1.68		30		4954000	30	20	b	1.50	Y	A
zinc dissolved	98/246	µg/L	5	U	10	U	4.78	J	191	-	4953990	191	180.33	a	1.06	Y	A

NOTES:
a=Utah 2017
b=Suter and Tsao 1996
c=USEPA 2017
d=USEPA 1996
e=Kim et al. 2013
f=CCME 2003

(1) Frequency of Detection Rules:
- Does not include field, rinsate or trip blanks
- Includes the maximum of the duplicate samples.

(2) The concentration selected to represent the exposure for this screening assessment was either the highest detected concentration (i.e., a "J" qualified value or an unqualified value) or the highest sample quantitation limit (for analytes that were not detected above the sample quantitation limit in any sample of this medium; i.e., a "U" qualified value).

(3) Contaminant Categories
A Contaminant was detected at concentrations exceeding its ecological screening value.
B Contaminant was not detected but SQL exceeded ecological screening value.
C Contaminant was detected but no Ecological Screening Value was available, constituent was retained.

Q = Qualifier Definitions
NO CODE -- Confirmed identification.
J -- Analyte present. Reported value is estimated; concentration is outside the range for accurate quantification.
B -- Not detected substantially above (10 times) the level reported in laboratory or field blanks.
U -- Not detected.

Table 7. Summary of the measured maximum surface water value pre-spill in the SJR and post GKM spill at each of the sampling locations. (Note: The bold font below indicates the maximum concentration for the six SJR stations. Shaded cells exceed the ESV).

COPC	Units	Ecological Screening Value	Pre-Spill Maximum Concentration		Post GKM Spill Entering UT							San Juan River (maximum concentration)
					4954000	4953990	4953880	4953250	4953000	4952942	4952940	
			Conc.	Location	SJR @ US 160 Xing in CO	SJR @ Town of Montezuma	SJR @ McElmo Wash	SJR @ Sand Island	SJR @Mexican Hat US163 Xing	SJR @ Clay Hills	SJR Above Lake Powell	
Aluminum dissolved	µg/L	87	4300	4953000	**20700**	1400	69.57	684	1790	1100	NA	20700
Antimony dissolved	µg/L	30	NM	NA	3	**3.458**	3	3	3	1.01	NA	3.458
Arsenic dissolved	µg/L	150	6	4953400[a]	**5.55**	1.58	1.74	2.03	2.33	2.89	NA	5.55
Barium dissolved	µg/L	4	278	4953000	**451**	314	224	294	445	411	NA	451
Beryllium dissolved	µg/L	0.66	NM	NA	**1.58**	1	1	1	1	0.067	NA	1.58
Cadmium dissolved	µg/L	1.31	NM	NA	0.261	**0.303**	0.1	0.1	0.1	NA	NA	0.303
Calcium dissolved	mg/L	116	NM	NA	74.1	95	**272**	85.6	87.9	239	NA	272
Chloride total	mg/L	230	NM	NA	16.2	20.9	**55.6**	21.2	24.7	35	NA	55.6
Chromium dissolved	µg/L	128.79	55	4952940	**12**	2	2	5.37	2	NA	NA	12
Cobalt dissolved	µg/L	23	NM	NA	**30**	30	30	30	30	1.08	NA	30
Copper dissolved	µg/L	20.68	25	4953400[a]	**27.7**	4.38	3.78	3.89	8.56	5.26	NA	27.7
Iron dissolved	mg/L	1.0	5.49	4953000	**16.7**	0.668	0.0775	0.328	0.787	0.774	NA	16.7
Lead dissolved	µg/L	1.99	20	4954000 4953800[b] 4952940	**15.7**	0.49	0.219	0.582	0.717	0.924	NA	15.7
Magnesium dissolved	mg/L	82	41	4952940	13.7	21.28	**181**	23.3	22.9	35.5	NA	181
Manganese dissolved	µg/L	120	314	4953000	**413**	26.5	69.1	9.5	19.7	16.1	NA	413
Mercury dissolved	µg/L	0.012	ND (0.1)	NA	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	NA	NA	0.2
Molybdenum dissolved	µg/L	240	NM	NA	3.65	2.84	5.51	5.31	**5.87**	4.27	NA	5.87
Nickel dissolved	µg/L	88.98	25	4952940	**12.7**	5	5	5	5	1.51	NA	12.7

Table 7. Continued.

Constituent	Units	Ecological Screening Value	Pre-Spill Maximum Concentration		Post GKM Spill Entering UT							
					4954000	**4953990**	**4953880**	**4953250**	**4953000**	**4952942**	**4952940**	**San Juan River (maximum concentration)**
			Conc.	Location	SJR @ US 160 Xing in CO	SJR @ Town of Montezuma	SJR @ McElmo Wash	SJR @ Sand Island	SJR @Mexican Hat US163 Xing	SJR @ Clay Hills	SJR Above Lake Powell	
Nitrate-nitrite-nitrogen total	mg/L	4	NM	NA	**46.4**	30.7	0.555	0.758	22.4	18.6	NA	46.4
Potassium dissolved	mg/L	53	10	4953250	**7.89**	6.46	6.78	5.25	5.14	7.19	NA	7.89
Selenium dissolved	µg/L	4.6	3	4954000	1.577	1.622	2.548	1.465	**2.97**	1.74	NA	2.97
Silver dissolved	µg/L	0.04	5	4952940	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	0.08	NA	0.5
Sodium dissolved	mg/L	680	NM	NA	89.6	72.7	**225**	70.7	71.7	67.5	NA	225
Strontium, dissolved	mg/L	1.5	NM	NA	0.816	0.957	**4.57**	0.980	1.03	1.06	NA	4.57
Sulfate total	mg/L	--	NM	NA	220	299	**1570**	264	262	795	NA	1570
Thallium dissolved	µg/L	0.8	NM	NA	0.18	0.1	0.1	0.16	**0.28**	0.05	NA	0.28
Vanadium dissolved	µg/L	20	NM	NA	**30**	**30**	**30**	**30**	**30**	12.6	NA	30
Zinc dissolved	µg/L	180.33	195	4953800[b]	72.8	**191**	13.4	20.4	30.1	20.6	NA	191

[a] – 4953400 San Juan River at Swinging Footbridge
[b] – 4953800 San Juan River below confluence with West Fork Allen Canyon

Table 8. Summary of sediment ecological screening values.

Constituent	Ecological Screening Values	Units	Source
Aluminum, total	25,500	mg/kg	Buchman 2008
Antimony, total	3	mg/kg	Buchman 2008
Arsenic, total	5.9	mg/kg	USEPA 2015
Barium, total	20	mg/kg	USEPA 2015
Beryllium, total	-	mg/kg	None
Cadmium, total	0.596	mg/kg	Buchman 2008
Calcium, total	-	mg/kg	None
Chromium, total	37.3	mg/kg	Buchman 2008
Cobalt, total	10	mg/kg	Buchman 2008
Copper, total	35.7	mg/kg	Buchman 2008
Iron, total	40,000	mg/kg	Buchman 2008
Lead, total	35	mg/kg	Buchman 2008
Mercury, total	0.174	mg/kg	Buchman 2008
Magnesium, total	-	mg/kg	None
Manganese, total	630	mg/kg	Buchman 2008
Molybdenum, total	200	mg/kg	MHSPE 1994
Nickel, total	18	mg/kg	Buchman 2008
Potassium, total	-	mg/kg	None
Selenium total	11	mg/kg	USEPA 2015
Silver, total	1	mg/kg	USEPA 1995a
Sodium, total	-	mg/kg	None
Strontium, total	49	mg/kg	Buchman 2008
Thallium, total	-	mg/kg	None
Vanadium, total	57	mg/kg	Buchman 2008
Zinc, total	123	mg/kg	Buchman 2008

Notes:
mg/kg - Milligrams per Kilogram
-- indicates an Ecological Screening Value does not exist for this analyte.

Table 9. Summary of Sediment COPCs for the San Juan River based on the maximum concentration for all five sampling locations.

Analyte	Frequency of Detection (1)	Range of Post Spill Sample Quantitation Limits (SQLs) (mg/kg)				Range of Post-Spill Detections (mg/kg)				Location (Sample ID) of Maximum Concentration	Concentration Used for Screening (2)	Ecological Screening Value			Maximum Ratio of Max Value Compared to Lowest Available Effects Threshold	Ration Greater than 1.0?	Contaminant Category (3)
		Min.	Q	Max	Q	Min.	Q	Max	Q			Value	Units	Ref.			
Ag	14/29	0.4	U	1.74	U	0.0243	J	0.0778	J	4952942	0.0778	1	mg/kg	a	0.08	N	--
Al	29/29	--	--	--	--	2720	B	16200	B	4954000	16200	25500	mg/kg	b	0.64	N	--
As	29/29	--	--	--	--	1.1	J	3.37	-	4954000	3.37	5.9	mg/kg	b	0.57	N	--
Ba	29/29	--	--	--	--	135.9		564		4954000	564	20	mg/kg	c	28.20	Y	A
Be	26/29	0.4	U	0.5	U	0.162	J	0.627	J	4954000	0.627	--	--	--	--	Y	C
Ca	29/29	--	--	--	--	4610	B	29479	-	4952942	29479	--	--	--	--	Y	C
Cd	21/25	0.1	--	0.1	--	0.0648	J	0.254	J	4954000	0.254	0.596	mg/kg	b	0.43	N	--
Co	29/29	--	--	--	--	1.41	-	4.36	-	4953990	4.36	10	mg/kg	b	0.44	N	--
Cr	29/29	--	--	--	--	2.32	J	12.4	-	4952942	12.4	37.3	mg/kg	b	0.33	N	--
Cu	28/29	1.49		1.49		1.85	J	9.9	J	4954000	9.9	35.7	mg/kg	b	0.28	N	--
Fe	29/29	--	--	--	--	3760	B	12100	B	4953990	12100	40000	mg/kg	b	0.30	N	--
Hg	19/29	0.0486	U	0.06	U	0.00182	JB	0.0228	J	4954000	0.0228	0.174	mg/kg	b	0.13	N	--
K	29/29	--	--	--	--	535		5080		4953990	5080	--	--	--	--	Y	C
Mg	29/29	--	--	--	--	1350	B	6580	-	4952942	6580	--	--	--	--	Y	C
Mn	29/29	--	--	--	--	132	-	279.7	-	4953990	279.7	630	mg/kg	b	0.44	N	--
Mo	6/29	0.4	U	23.2	U	0.355	J	0.578	J	4953990	0.578	200	mg/kg	d	0.00	N	
Na	29/29	--	--	--	--	113	J	517	B	4953990	722	--	--	--	--	Y	C
Ni	28/29	2.12	U	2.12	U	2.15	J	11.1	-	4952942	11.1	18	mg/kg	b	0.62	N	--
Pb	26/29	3.32	U	4.02	U	2.99	J	9.6	-	4953990	9.6	35	mg/kg	b	0.27	N	--
Sb	0/29	0.4	U	4.63	U	--	--	--	--	4952942	4.63	3	mg/kg	b	1.54	Y	B
Se	5/29	0.484	U	0.632	U	2.1	--	3.8	--	4953990	3.8	11	mg/kg	c	0.35	N	--
Sr	5/5	--	--	--	--	74.2		133.1	--	4952942	133.1	49	mg/kg	b	2.72	Y	A
Tl	24/29	0.1	--	0.1	--	0.0334	J	0.181	J	4954000	0.181	--	--	--	--	Y	C
V	29/29	--	--	--	--	6.74	J	28.1	-	4954000	28.1	57	mg/kg	b	0.49	N	--
Zn	25/25	--	--	--	--	10.4	J	34.3	J	4954000	34.3	123	mg/kg	b	0.28	N	--

NOTES:

References:
a=USEPA 1995a
b=Buchman 2008
c=USEPA 2015
d=Ministry of Housing, Spatial Planning and Environment 1994

(1) Frequency of Detection Rules:
- Does not include field, rinsate or trip blanks
- Includes the maximum of the duplicate samples.

(2) The concentration selected to represent the exposure for this screening assessment was either the highest detected concentration (i.e., a "J" qualified value or an unqualified value) or the highest sample quantitation limit (for analytes that were not detected above the sample quantitation limit in any sample of this medium; i.e., a "U" qualified value).

(3) Contaminant Categories
A Contaminant was detected at concentrations exceeding ecological screening value.
B Contaminant was not detected but SQL exceeded ecological screening value.
C Contaminant was detected but no Ecological Screening Value is available, constituent was retained.

Q = Qualifier Definitions
NO CODE -- Confirmed identification.
J -- Analyte present. Reported value is estimated; concentration is outside the range for accurate quantification.
B -- Not detected substantially above (10 times) the level reported in laboratory or field blanks.
U -- Not detected.

Table 10. Summary of maximum sediment concentrations at each sampling point on the main stem SJR, as well as the maximum concentration measured across all sampling locations representing the SJR in Utah. (Note: The bold font below indicates the maximum concentration for the five SR stations. Shaded cells indicate exceedances of the ESV.)

Constituent	Units	Ecological Screening Value (ESV)	Pre-Spill		Post GKM Spill Entering UT					San Juan River (maximum concentration)
					4954000	4953990	4953250	4953000	4952940/42	
			Conc.	Location	SJR @ US 160 Xing in CO	SJR @ Town of Montezuma	SJR @ Sand Island	SJR @Mexican Hat US163 Xing	SJR @ Clay Hills	
Aluminum	mg/kg	25500	**16600**	4954000	16200	14600	10600	6350	14400	16600
Antimony	mg/kg	3[a]	ND (4.42)	4953000	ND (4.48)	ND (4.48)	ND (4.13)	ND (4.0)	**ND (4.63)**	ND (4.63)
Arsenic	mg/kg	5.9	**3.76**	4954000	**3.37**	3.23	2.78	2.49	2.99	3.76
Barium	mg/kg	20	279	4953990	**564**	234.3	518	411	251	564
Beryllium	mg/kg	NA[b]	**0.675**	4954000	0.627	0.566	0.451	0.327	0.552	0.675
Cadmium	mg/kg	0.596	**0.309**	4954000	0.254	0.242	0.17	0.166	0.201	0.309
Calcium	mg/kg	NA[b]	21900	4954000	19321	22523	16704	17300	**29479**	29479
Chromium	mg/kg	37.3	**14.2**	4954000	12.1	10.4	9.53	5.61	12.4	14.2
Cobalt	mg/kg	10	4.12	4954000	**4.36**	4.35	3.19	2.71	3.81	4.36
Copper	mg/kg	35.7	8.65	4954000	**9.9**	9.5	6.35	4.4	5.56	9.9
Iron	mg/kg	40000	11400	4954000	11900	**12100**	9630	7790	10400	12100
Lead	mg/kg	35	9.03	4954000	8.52	**9.6**	6.5	5.19	7.2	9.6
Magnesium	mg/kg	NA[b]	**7060**	4954000	4715	5550	3325	4120	6580	7060
Manganese	mg/kg	630	**280**	4954000	251	279.7	232.7	207	269.7	280
Mercury	mg/kg	0.174	0.00182	4954000	**0.0228**	0.00757	0.00301	0.00375	0.00655	0.0228
Molybdenum	mg/kg	200	0.43	4953000	0.507	**0.578**	ND (0.339)	ND (0.356)	ND (0.413)	0.578
Nickel	mg/kg	18	8.11	4954000	7.07	8.3	4.96	4.87	**11.1**	11.1
Potassium	mg/kg	NA[b]	4870	4954000	3810	**5080**	2540	1590	4220	5080
Selenium	mg/kg	11	ND (0.602)	4953000	2.1	**3.8**	2.7	2.4	2.4	3.8
Silver	mg/kg	1	0.0679	4953000	0.0504	0.0367	0.0243	ND (0.0224)	**0.0778**	0.0778
Sodium	mg/kg	NA[b]	**722**	4954000	440	517	331.6	269	337.4	722
Strontium	mg/kg	49	NM	NM	97.7	114.7	99.4	74.2	**133.1**	133.1
Thallium	mg/kg	NA[b]	**0.181**	4954000	0.172	0.171	0.131	0.0844	0.114	0.181
Vanadium	mg/kg	57	**29.4**	4954000	28.1	26.7	22.9	14.6	22	29.4
Zinc	mg/kg	123	**40.1**	4954000	34.3	33.1	26.7	18.4	25.1	40.1

[a] – Antimony was not detected in any sediment samples pre- or post-spill, however the detection level is in excess of the screening value, so it will be discussed in the Uncertainties Section.

[b] – Due to the lack of a sediment based screening value, these constituents will be discussed in the uncertainties section. Ca, Mg, K, and Na are considered essential nutrients and do not pose risk.

Table 11. Summary of constituents identified as COPCs in the San Juan River sediment and surface water after Step 1 of the ERA process.

Constituent	Number of Sampling Locations with Maximum Concentration > ESV or No ESV		Identified COPC Using SJR Maximum Concentration	
	Sediment	Surface Water	Sediment	Surface Water
Aluminum	0/5	5/7		**X**
Antimony	0/5	0/7	**U[a]**	
Arsenic	0/5	0/7		
Barium	5/5	6/7	**X**	**X**
Beryllium	No ESV	6/7	**U[b]**	**X**
Cadmium	0/5	0/7		
Calcium	No ESV	1/7	**U[c]**	**U[c]**
Chloride	0/5	0/7		
Chromium	0/5	0/7		
Cobalt	0/5	5/7		**X**
Copper	0/5	1/7		**X**
Iron	0/5	1/7		**X**
Lead	0/5	2/7		**X**
Magnesium	No ESV	1/7	**U[c]**	**U[c]**
Manganese	0/5	1/7		**X**
Mercury	0/5	5/7		**X**
Molybdenum	0/5	0/7		
Nickel	0/5	0/7		
Nitrate-Nitrite-Nitrogen	0/5	4/7		**X**
Potassium	No ESV	0/7	**U[c]**	
Selenium	0/5	0/7		
Silver	0/5	6/7		**X**
Sodium	No ESV	0/7	**U[c]**	
Strontium	5/5	1/7	**X**	**X**
Sulfate	0/5	No ESV		**U[b]**
Thallium	No ESV	0/7	**U[b]**	
Vanadium	0/5	5/7		**X**
Zinc	0/5	1/7		**X**

Notes:
X - COPC
U[a] = Moved to Uncertainties due to maximum detection limit was in excess of ecological screening value
U[b] = Moved to Uncertainties due to lack of approved ecological screening value
U[c] = Ca, Mg, K, and Na are considered essential nutrients and although Ca and Mg exceeded ESV in surface water at 1 location, these constituents are being moved to the Uncertainties section and will be discussed further.
Chemicals without notation under specific media have been through this screening level and are not considered a COPC.
As a result, the chemical for the specific media does not advance to the next step in the screening level assessment.

Table 12. Summary of aquatic-dependent wildlife receptors of concern and the exposure factors used in the Step 2 SLERA.

Receptor	Exposure Factor			
	Body Weight (kg)	**Food Ingestion Rate (kg dw/kg-bw/day)**	**Water Ingestion Rate (L/kg-bw/day)**	**Incidental Sediment Ingestion Rate (Percentage of Food Ingestion Rate) (kg dw/kg-bw/day)**
Raccoon	3.67 – 7.6 (USEPA 1993)	0.050 (allometric equation[1]; Nagy 2001)	0.167 (allometric equation[7]; Calder and Braun 1983)	0.0047 (9.4%) (Beyer et al. 1994)
Mink	0.533 – 2.3 (USEPA 1993)	0.183 (allometric equation[2]; Nagy 2001)	0.393 (allometric equation[7]; Calder and Braun 1983)	0.0037 (2%) (US Army 2006)
Muskrat	0.837 – 1.55 (USEPA 1993)	0.103 (allometric equation[3]; Nagy 2001)	0.175 (allometric equation[7]; Calder and Braun 1983)	0.0097 (9.4%) (Beyer et al. 1994)
Mallard	1.043 – 1.355 (USEPA 1993)	0.059 (allometric equation[4]; Nagy 2001)	0.069 (allometric equation[8]; Calder and Braun 1983)	0.002 (3.3%) (Beyer et al. 1994)
Belted Kingfisher	0.1204 – 0.1695 (USEPA 1993)	0.097 (allometric equation[5]; Nagy 2001)	0.070 (allometric equation[8]; Calder and Braun 1983)	Negligible (0%) (US Army 2006)
Great Blue Heron	1.467 – 2.875 (USEPA 1993)	0.114 (allometric equation[5]; Nagy 2001)	0.082 (allometric equation[8]; Calder and Braun 1983)	Negligible (0%) (US Army 2006)
Bullfrog	0.0658 – 0.274 (USEPA 1993)	0.43 (using allometric equation[6]; Nagy 2001)	0.38 (allometric equation[8]; Calder and Braun 1983)	0.002 (1.2%) (Bush 1959)

Notes:

[1] – $FIR = (0.432(\text{max } BW)^{0.678})/\text{min } BW$ [2] – $FIR = (0.153(\text{max } BW)^{0.834})/\text{min } BW$

[3] – $FIR = (0.859(\text{max } BW)^{0.628})/\text{min } BW$ [4] – $FIR = (0.670(\text{max } BW)^{0.627})/\text{min } BW$

[5] – $FIR = 0.849(\text{max } BW)^{0.663})/\text{min } BW$ [6] – $FIR = (0.540(\text{max } BW)^{0.705})/\text{min } BW$

[7] – $WIR = (0.099(\text{max } BW)^{0.90})\text{min } BW$ [8] – $WIR = (0.059(\text{max } BW)^{0.67})/\text{min } BW$

Kg – Kilogram

Kg/day-dry – Kilograms per Day – dry weight

L/day – Liters per Day

References are shown in parentheses and provided in Section 9.0

*The bullfrog's food and water ingestion rates were calculated with allometric equation, which are typically used for birds. There was no equation available for amphibians.

Table 13. Summary of BAF/BCF values used in the SJR screening level ERA

COPC	Benthic Invertebrate Bioaccumulation Factors (dw)	Reference	Aquatic Plant Bioconcentration Factors (dw)	Ref.	Fish Bioconcentration Factors from Surface Water (dw)	Ref.	Fish Bioaccumulation Factors from Sediment (dw)	Ref.
Aluminum	1.186	a	1	assumed	2.7	g, h	1	assumed
Barium	1.186	a	0.156	e	633	a	1	assumed
Beryllium	1.186	a	$Cp = 10^{(-0.536+0.7345*(\log Csed))}$	d	62	i, k, l	1	assumed
Cobalt	1.186	a	0.0075	d, f	1	assumed	1	assumed
Copper	$Ci = 10^{(0.278+1.089(\log Csed))}$	b	$Cp = 10^{(0.668+0.394*(\log Csed))}$	f	2,840	a	0.1	p
Iron	1	assumed	1	assumed	1	assumed	1	assumed
Lead	$Ci = 10^{(-0.515+0.653(\log Csed))}$	b	$Cp = 10^{(-1.328+0.561*\log(Csed))}$	d, f	640	m	0.07	p
Manganese	1.186	a	0.079	d, f	1	assumed	1	assumed
Mercury	1.186	b	$Cp = 10^{(-0.966+0.544*\log(Csed))}$	f	14,120	a	3.25	q
Nitrate-nitrite-nitrogen, total	1	assumed	1	Assumed	1	assumed	1	assumed
Silver	0.18	c	0.014	d	112	n	1	assumed
Strontium	1.186	a	1	assumed	60	r	1	assumed
Vanadium	1.186	a	0.00485	f	1	assumed	1	assumed
Zinc	$Ci = 10^{(1.89+0.126(\log Csed))}$	b	$Cp = 10^{(1.575+0.554*\log(Csed))}$	f	2,556	a	0.147	o

Notes:
dw – Dry Weight
COPC – Constituent of Potential Concern
When BAF or BCF data were not available a default value of 1.0 was assumed.

a = USEPA, 1999b
b = Bechtel Jacobs, 1998a
c = Hirsch, 1998
d = USEPA, 2007
e = Baes et al., 1984
f = Bechtel Jacobs, 1998b
g = Cleveland et al., 1986
h = Cleveland et al., 1991
i = Thompson et al., 1972
k = USEPA, 1978
l = USEPA, 1992
m = AQUIRE, 2002
n = USEPA, 1996
o = Pascoe et al., 1996
p = Krantzberg and Boyd, 1992
q = Cope et al., 1990
r = NCRP, 1996

Table 14. No Observed Adverse Effect Levels (as mg/kg-bw/day) used in the SJR screening-level ERA

COPC	Raccoon	Ref.	Muskrat	Ref.	Mink	Ref.	Mallard	Ref.	Kingfisher	Ref.	Great Blue Heron	Ref.	Bullfrog	Ref.
Aluminum	0.58	a	0.84	a	0.94	a	109.7	a	109.7	a	109.7	a	109.7	a
Barium	2.99	a	4.33	a	4.85	a	20.8	a	20.8	a	20.8	a	20.8	a
Beryllium	<0.21	b	<0.31	b	<0.35	b	NA	--	NA	--	NA	--	NA	--
Cobalt	0.43	c	0.6	c	0.7	c	3.89	g	3.89	g	3.89	g	3.89	g
Copper	8.45	a	33.94	d	13.69	a	47	a	47	a	47	a	47	a
Iron	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--
Lead	4.45	a	6.43	a	7.2	a	1.13	a	1.13	a	1.13	a	1.13	a
Manganese	48.9	a	70.76	a	79.22	a	977	a	977	a	977	a	977	a
Mercury	0.72	a	5.74	a	1.17	a	0.026	g	0.49	i	0.49	i	0.026	h
Nitrate-Nitrite-Nitrogen	352.75	a	510.45	a	571.41	a	NA	--	NA	--	NA	--	NA	--
Silver	5.03	e	7.29	e	8.16	e	7	j	7	j	7	j	7	j
Strontium	146.15	a	211.49	a	236.75	a	NA	--	NA	--	NA	--	NA	--
Vanadium	0.11	a	0.16	a	0.18	a	11.4	a	11.4	a	11.4	a	11.4	a
Zinc	15.03	f	128.66	a	24.34	f	14.5	a	14.5	a	14.5	a	14.5	a

Notes:
mg/kg - bw/day - Milligrams per Kilograms Body Weight per Day
NA – Not Available

a = Sample et al. 1996
b = Goel et al., 1980
c = Nation et al., 1983 from Eco-SSL
d = ATSDR 1990a
e = ATSDR 1990b
f = ATSDR 1994
g = Hill, 1979 from Eco-SSL
h = USEPA 1997b
i = USEPA 1995
j = Eisler 1996

Table 15. Lowest Observed Adverse Effect Levels (as mg/kg – bw/day) used in the SJR screening-level ERA

COPC	Raccoon	Ref.	Muskrat	Ref.	Mink	Ref.	Mallard	Ref.	Kingfisher	Ref.	Great Blue Heron	Ref.	Bullfrog	Ref.
Aluminum	5.8	a	8.4	a	9.4	a	>109.7	a	>109.7	a	>109.7	a	>109.7	a
Barium	2.99	a	4.33	a	4.85	a	41.7	a	41.7	a	41.7	a	41.7	a
Beryllium	0.21	b	0.31	b	0.35	b	NA	--	NA	--	NA	--	NA	--
Cobalt	1.74	b	2.5	c	2.82	c	7.8	g	7.8	g	7.8	g	7.8	g
Copper	10.91	a	45.25	d	17.67	a	61.7	a	61.7	a	61.7	a	61.7	a
Iron	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--
Lead	44.46	a	64.33	a	72.02	a	11.3	a	11.3	a	11.3	a	11.3	a
Manganese	157.82	a	228.38	a	255.65	a	>977	a	>977	a	>977	a	>977	a
Mercury	3.61	a	28.72	a	5.85	a	0.078	h	1.2	i	1.2	i	0.078	h
Nitrate-Nitrite-Nitrogen	786.21	a	1137.68	a	1273.57	a	NA	--	NA	--	NA	--	NA	--
Silver	25.17	e	36.43	e	40.78	e	35	j	35	j	35	j	35	j
Vanadium	1.08	a	1.57	a	1.76	a	>11.4	a	>11.4	a	>11.4	a	>11.4	a
Zinc	75.14	f	257.33	a	121.72	f	131	a	131	a	131	a	131	a

Notes:
mg/kg - bw/day - Milligrams per Kilograms Body Weight per Day
NA – Not Available

a = Sample et al. 1996
b = Goel et al., 1980
c = Nation et al., 1983 from Eco-SSL
d = ATSDR 1990a
e = ATSDR 1990b
f = ATSDR 1994
g = Hill, 1979 from Eco-SSL
h = USEPA 1997b
i = USEPA 1995
j = Eisler 1996

Table 16. Summary of post-GKM spill EQ_{max} with respect to benthic invertebrates / aquatic plants and sediment COPCs.

COPC	Sediment Maximum (mg/kg)	Ecological Screening Value (mg/kg)	ESV Source	Ecological Quotient (EQmax)
Barium	564	20	USEPA 2015	**28.2**
Strontium	133.100	49	Buchman 2008	**2.7**

Notes:
Bold - The EQ value is either above the TRV or there is no published TRV value. As a result, the analyte must be considered in the next step.
mg/kg - Milligrams per
Kilogram
EQ_{max} - Ecological Quotient Maximum
COPC - Constituent of Potential Concern

Table 17. Summary of post-GKM spill EQ_{max} with respect to aquatic water column communities including fish and surface water COPCs.

COPC	Surface Water Maximum (µg/L)	Ecological Screening Value (µg/L)	ESV Source	Ecological Quotient (EQmax)
Aluminum	20700	87	a	**238**
Barium	451	4	b	**113**
Beryllium	1.58	0.66	b	**2.4**
Cobalt	30	23	b	**1.3**
Copper	30	20.68	a	**1.5**
Iron	16700	1000	c	**16.7**
Lead	15.7	1.99	a	**7.9**
Manganese	413	120	b	**3.4**
Mercury	0.2	0.012	a	**16.7**
Nitrate-Nitrite-Nitrogen	46.4	4	a	**11.6**
Silver	0.5	0.04	a	**12.5**
Strontium	4570	1500	b	**3.0**
Vanadium	30	20	b	**1.5**
Zinc	191	180.33	a	**1.1**

Notes:
a = Utah 2017
b = Suter and Tsao 1996
c = USEPA 2017
NA* = These COPCs move forward to the next step due to uncertainties

Bold - The EQ value is either above the TRV or there is no published TRV value. As a result, the analyte must be considered in Step 3.
µg/L - Micrograms per Liter
EQ_{max} - Ecological Quotient Maximum
COPC - Constituent of Potential Concern

Table 18. Results of post-GKM spill screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**1793**	**179**	**2548**	**255**	**3813**	**381**	**19.1**	**<19.1**	**17**	**<17**	**17.5**	**<17.5**	**76.1**	**<76.1**
Barium	**15.4**	**<15.4**	**21.9**	**<21.9**	**33.2**	**<33.2**	**3.5**	**1.8**	**4.1**	**2.0**	**4.8**	**2.4**	**18.1**	**9.0**
Beryllium	>0.2	0.2	**NA**	0.3	**NA**	0.4	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	0.7	0.2	0.9	0.2	**1.4**	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.6	0.3
Copper	0.5	0.4	0.3	0.2	**1.1**	0.8	0.04	0.03	0.2	0.1	0.2	0.2	0.7	0.6
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.1	0.01	0.2	0.02	0.3	0.03	0.6	0.06	**2.3**	0.1	**2.7**	0.1	**4.1**	0.4
Manganese	0.4	0.1	0.5	0.2	0.8	0.2	0.04	<0.04	0.03	<0.03	0.03	<0.03	0.2	<0.2
Mercury	0.2	0.04	0.05	0.01	0. 5	0.1	0.1	0.04	0.6	0.2	0. 7	0.3	**48**	**16**
Nitrate-Nitrite-Nitrogen	0.03	0.01	0.03	0.01	0.05	0.02	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.001	0.0003	0.002	0.0004	0.003	0.001	0.001	0.0002	0.002	0.0004	0.002	0.00047	0.01	0.002
Strontium	0.2	<0.2	0.2	<0.2	0.3	<0.3	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**16.7**	**1.7**	**23.7**	**2.4**	**35.4**	**3.5**	0.3	<0.32	0.3	<0.3	0.01	<0.01	**1.3**	**<1.3**
Zinc	**1.7**	0.3	0.4	0.2	**3.7**	0.8	**1.2**	0.1	**3.3**	0.4	**3.9**	0.4	**14.7**	**1.6**

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 19. Summary of post-GKM spill COPCs retained after Step 2 of the screening level ERA.

COPC	Surface Water								Sediment							
	Water Column Communities	Raccoon	Muskrat	Mink	Mallard	Belted Kingfisher	Great Blue Heron	Bullfrog	Benthic Invertebrates	Raccoon	Muskrat	Mink	Mallard	Belted Kingfisher	Great Blue Heron	Bullfrog
Aluminum	X	X	X	X	X	X	X	X								
Barium	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beryllium	X															
Cobalt	X			X												
Copper	X			X												
Iron	X															
Lead	X					X	X	X								
Manganese	X															
Mercury	X							X								
Nitrate-Nitrite-Nitrogen	X															
Silver	X															
Strontium	X								X							
Vanadium	X	X	X	X				X								
Zinc	X	X		X	X	X	X	X								

Notes:

X - COPC remaining after Step 2

No toxicological data available.

Table 20. Results of pre-GKM spill screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**1832**	**183**	**2607**	**261**	**3900**	**390**	**19.5**	**<19.5**	**17.41**	**<17.4**	**17.8**	**<17.8**	**77.9**	**<77.9**
Barium	**8.2**	**<8.2**	**11.7**	**<11.7**	**17.7**	**<17.7**	**1.7**	0.9	**2.2**	1.1	**2.5**	**1.3**	**9.7**	**4.8**
Beryllium	>0.2	0.2	>0.3	0.3	>0.4	0.4	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	NA	NA	0.9	0.2	**1.3**	0.3	0.1	0.07	0.1	0.06	0.1	0.06	0.5	0.3
Copper	0.4	0.3	0.2	0.2	1.0	0.8	0.04	0.03	0.1	0.1	0.2	0.1	0.7	0.5
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.2	0.02	0.2	0.02	0.3	0.03	0.5	0.05	**2.9**	0.1	**3.4**	0.1	**5.2**	0.5
Manganese	0.4	0.1	0.5	0.2	0.8	0.2	0.04	<0.03	0.03	<0.03	0.03	<0.03	0.1	<0.1
Mercury	0.1	0.02	0.03	0.01	0.2	0.04	0.01	0.00	0.3	0.1	0.3	0.1	**23.5**	**7.8**
Nitrate-Nitrite-Nitrogen	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.001	0.0003	0.002	0.0004	0.003	0.001	0.001	0.0001	0.002	0.0003	0.002	0.0004	0.01	0.002
Strontium	0.00	<0.2	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**17.4**	**1.7**	**24.7**	**2.5**	**37.0**	**3.7**	0.3	<0.3	0.3	<0.3	0.01	<0.009	**1.3**	**<1.3**
Zinc	**1.7**	0.3	0.4	0.2	**3.8**	0.8	**1.3**	0.1	**3.4**	0.4	**4.0**	0.4	**15.1**	**1.7**

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 21. Results of post-GKM spill Location 4954000 - SJR @ US 160 Xing in CO screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**1793**	**179**	**2548**	**255**	**3813**	**381**	**19.1**	**<19.1**	**17.0**	**<17.0**	**17.4**	**<17.5**	**76.1**	**<76.1**
Barium	**12.1**	**<12.1**	**17.2**	**<17.2**	**25.7**	**<25.7**	**3.5**	**1.7**	**3.1**	**1.6**	**4.8**	**2.4**	**14.0**	**7.0**
Beryllium	>0.2	0.2	**NA**	0.3	**NA**	0.4	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	0.7	0.2	0.9	0.2	**1.4**	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.6	0.3
Copper	0.1	0.1	0.2	0.2	**1.1**	0.8	0.04	0.03	0.2	0.1	0.2	0.1	0.7	0.6
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.1	0.01	0.2	0.02	0.3	0.03	0.5	0.05	**2.3**	0.09	**2.7**	0.1	**4.1**	0.4
Manganese	0.3	0.1	0.5	0.1	0.7	0.2	0.03	<0.03	0.03	<0.03	0.03	<0.0001	0.1	<0.1
Mercury	0.2	0.04	0.05	0.01	0.5	0.09	0.1	0.04	0.6	0.2	0.7	0.3	**47.9**	**16.0**
Nitrate-Nitrite-Nitrogen	0.03	0.01	0.03	0.01	0.05	0.02	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.001	0.0002	0.002	0.0003	0.002	0.0005	0.001	0.0001	0.0001	0.00003	0.002	0.0003	0.007	0.001
Strontium	0.06	<0.06	0.08	<0.08	0.1	<0.1	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**16.6**	**1.7**	**23.7**	**2.4**	**35.4**	**3.5**	0.3	<0.3	0.3	<0.3	0.01	<0.01	**1.3**	**<1.3**
Zinc	0.7	0.1	0.2	0.08	**1.5**	0.3	**1.2**	0.1	**1.3**	0.1	**1.5**	0.2	**5.8**	0.6

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 22. Results of post-GKM spill Location 4953990 - SJR @ Town of Montezuma screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**1611**	**161**	**2293**	**229**	**3429**	**343**	**17.2**	**<17.2**	**15.3**	**<15.3**	**15.7**	**<15.7**	**68.5**	**<68.5**
Barium	**5.0**	**<5.0**	**7.1**	**<7.1**	**10.7**	**<10.7**	**1.5**	0.7	**1.3**	0.6	**2.4**	1.2	**5.8**	**2.9**
Beryllium	>0.2	0.2	>0.2	0.2	>0.4	0.4	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	0.7	0.2	0.9	0.2	**1.4**	0.3	0.1	0.07	0.1	0.06	0.1	0.07	0.6	0.3
Copper	0.1	0.1	0.05	0.03	0.2	0.1	0.04	0.03	0.03	0.02	0.03	0.03	0.1	0.1
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.02	0.002	0.03	0.003	0.03	0.003	0.6	0.06	0.2	0.01	0.3	0.01	0.4	0.04
Manganese	0.4	0.1	0.5	0.2	0.8	0.2	0.04	<0.04	0.03	<0.03	0.03	<0.03	0.1	<0.1
Mercury	0.2	0.04	0.05	0.01	0.4	0.09	0.04	0.01	0.6	0.2	0.7	0.3	**47.1**	**15.7**
Nitrate-Nitrite-Nitrogen	0.02	0.01	0.02	0.01	0.03	0.01	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.001	0.0002	0.001	0.0003	0.002	0.0004	0.0004	0.0001	0.0001	0.00002	0.002	0.0003	0.006	0.001
Strontium	0.06	<0.06	0.09	<0.09	0.1	<0.1	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**15.8**	**1.6**	**22.5**	**2.2**	**33.6**	**3.4**	0.3	<0.3	0.3	<0.3	0.01	<0.009	**1.2**	**<1.2**
Zinc	**1.7**	0.3	0.4	0.2	**3.7**	0.7	**1.2**	0.1	**3.3**	0.4	**3.9**	0.4	**14.7**	**1.6**

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 23. Results of post-GKM spill Location 4953250 - SJR @ Sand Island screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**1169**	**117**	**1665**	**166**	**2489**	**249**	**12.5**	**<12.5**	**11.1**	**<11.1**	**11.4**	**<11.4**	**49.8**	**<49.8**
Barium	**11.1**	**<11.1**	**15.8**	**<15.8**	**23.6**	**<3.6**	**3.2**	**1.6**	**2.9**	**1.4**	**4.0**	**2.0**	**12.8**	**6.4**
Beryllium	>0.1	0.1	>0.2	0.2	>0.3	0.3	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	0.5	0.1	0.7	0.2	**1.0**	0.3	0.1	0.1	0.1	0.05	0.1	0.05	0.4	0.2
Copper	0.09	0.07	0.04	0.03	0.2	0.1	0.03	0.02	0.02	0.02	0.03	0.02	0.1	0.08
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.02	0.002	0.02	0.002	0.03	0.003	0.4	0.04	0.2	0.01	0.2	0.01	0.4	0.04
Manganese	0.3	0.09	0.4	0.1	0.6	0.2	0.03	<0.03	0.03	<0.03	0.03	<0.03	0.1	<0.1
Mercury	0.2	0.04	0.05	0.01	0.4	0.09	0.02	0.01	0.6	0.2	0.7	0.3	**46.9**	**15.6**
Nitrate-Nitrite-Nitrogen	0.0005	0.0002	0.0004	0.0002	0.001	0.0003	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.001	0.0002	0.001	0.0002	0.002	0.0004	0.0002	0.00005	0.0001	0.00001	0.001	0.0003	0.005	0.001
Strontium	0.06	<0.06	0.08	<0.08	0.1	<0.1	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**13.6**	**1.4**	**19.3**	**1.9**	**28.9**	**2.9**	0.3	<0.3	0.2	<0.2	0.01	<0.008	**1.0**	<1.0
Zinc	0.2	0.04	0.05	0.02	0.4	0.09	**1.1**	0.1	0.4	0.04	0.5	0.05	**1.8**	0.2

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 24. Results of post-GKM spill Location 4953000 - SJR @Mexican Hat US163 Xing screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**701**	**70.1**	**997**	**99.7**	**1492**	**149**	**7.5**	**<7.5**	**6.7**	**<6.7**	**6.8**	**<6.8**	**29.8**	**<29.8**
Barium	**8.8**	**<8.8**	**12.5**	**<12.5**	**18.7**	**<18.7**	**2.5**	**1.3**	**2.3**	**1.1**	**3.9**	**1.9**	**10.2**	**5.1**
Beryllium	>0.10	0.10	>0.1	0.1	>0.2	0.2	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	0.4	0.1	0.6	0.1	0.9	0.2	0.09	0.05	0.08	0.04	0.08	0.04	0.4	0.2
Copper	0.06	0.05	0.08	0.06	0.3	0.3	0.02	0.01	0.05	0.04	0.06	0.05	0.2	0.2
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.02	0.002	0.02	0.002	0.02	0.002	0.3	0.03	0.2	0.01	0.2	0.01	0.3	0.03
Manganese	0.3	0.08	0.4	0.1	0.6	0.2	0.03	<0.03	0.02	<0.02	0.02	<0.02	0.1	<0.1
Mercury	0.2	0.04	0.05	0.01	0.4	0.09	0.02	0.01	0.6	0.2	0.7	0.3	**46.9**	**15.6**
Nitrate-Nitrite-Nitrogen	0.01	0.01	0.01	0.01	0.02	0.01	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.0008	0.0002	0.001	0.0002	0.002	0.0004	0.0002	0.00005	0.0001	0.00001	0.001	0.0003	0.005	0.001
Strontium	0.05	<0.05	0.07	<0.07	0.1	<0.1	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**8.7**	0.9	**12.3**	**1.2**	**18.4**	**1.8**	0.2	<0.2	0.1	<0.1	0.01	<0.005	0.7	<0.7
Zinc	0.3	0.06	0.07	0.03	0.6	0.1	0.8	0.09	0.6	0.06	0.7	0.07	**2.5**	0.3

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 25. Results of post-GKM spill Location 4952942 - SJR @ Clay Hills screening level ERA Step 2 food web model for upper trophic level receptors of concern. Bold values represent HQ_N or HQ_L in excess of 1.0 or lacking TRVs.

COPC	Raccoon		Muskrat		Mink		Mallard		Belted Kingfisher		Great Blue Heron		Bullfrog	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L	HQ_N	HQ_L
Aluminum	**1588**	**159**	**2261**	**226**	**3382**	**338**	**16.9**	**<16.9**	**15.1**	**<15.1**	**15.4**	**<15.4**	**67.6**	**<67.6**
Barium	**5.4**	**<5.4**	**7.7**	**<7.7**	**11.5**	**<11.5**	**1.6**	0.8	**1.4**	0.7	**2.8**	**1.4**	**6.2**	**3.1**
Beryllium	>0.2	0.1	**NA**	0.2	**NA**	0.4	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Cobalt	0.6	0.1	0.8	0.2	**1.2**	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.3
Copper	0.08	0.06	0.05	0.04	0.2	0.2	0.02	0.02	0.03	0.02	0.04	0.03	0.1	0.1
Iron	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Lead	0.02	0.002	0.03	0.003	0.03	0.003	0.4	0.04	0.2	0.01	0.3	0.01	0.5	0.05
Manganese	0.4	0.1	0.5	0.2	0.8	0.2	0.04	<0.04	0.03	<0.03	0.03	<0.03	0.1	<0.1
Mercury	0.002	0.0003	0.0004	0.0001	0.003	0.001	0.03	0.01	0.004	0.002	0.01	0.002	0.4	0.1
Nitrate-Nitrite-Nitrogen	0.01	0.01	0.01	0.005	0.02	0.01	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Silver	0.001	0.0002	0.001	0.0003	0.002	0.0004	0.0008	0.0002	0.0002	0.00004	0.001	0.0003	0.005	0.001
Strontium	0.07	<0.07	0.1	<0.1	0.2	<0.2	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Vanadium	**13.0**	**1.3**	**18.5**	**1.9**	**27.7**	**2.8**	0.2	<0.2	0.2	<0.2	0.01	<0.007	**1.0**	<1.0
Zinc	0.2	0.04	0.05	0.02	0.5	0.09	**1.0**	0.1	0.4	0.04	0.5	0.05	**1.8**	0.2

Notes:
NA = Not Applicable.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
HQ_N = Hazard Quotient based on NOAEL
HQ_L = Hazard Quotient based on LOAEL

Table 26. Ecological Risk Assessment Summary for post-GKM spill in the SJR..

Assessment Endpoint	Measurement Endpoint	Result
Ecological health of aquatic water column communities including fish	Evaluation of surface water chemistry with respect to water quality standards	• EQ_{max} based on the maximum surface water concentration was > 1.0 for Al, Ba, Be, Co, Cu, Fe, Pb, Mn, Hg, NO_3^-,NO_2^-,N, Ag, Sr, V, and Zn to aquatic water column communities including fish.
Ecological health of benthic invertebrate and aquatic plant communities	Evaluation of sediment chemistry with respect to sediment ecological screening values	• EQ_{max} based on the maximum sediment concentration was > 1.0 for Ba and Sr to benthic invertebrates and aquatic plant communities.
Long-term health and reproductive capacity of omnivorous aquatic avian species (mallard duck)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Ba, and Zn indicating potential risk to omnivorous aquatic avian species.
Long-term health and reproductive capacity of carnivorous aquatic avian species (blue heron)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Ba, Pb, and Zn indicating potential risk carnivorous aquatic avian species.
Long-term health and reproductive capacity of piscivorous aquatic avian species (belted kingfisher)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Ba, Pb, and Zn indicating potential risk to piscivorous aquatic avian species.
Long-term health and reproductive capacity of omnivorous aquatic mammalian species (raccoon)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Ba, V, and Zn indicating potential risk to omnivorous aquatic mammalian species.
Long term health and reproductive capacity of omnivorous aquatic rodent species (muskrat)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Ba, and V indicating potential risk to omnivorous aquatic rodent species.
Long term health and reproductive capacity of omnivorous aquatic mammal species (mink)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Va, Co, Cu, V, and Zn indicating potential risk to omnivorous aquatic mammalian species.
Long term health and reproductive capacity of omnivorous aquatic amphibian species (bullfrog)	Evaluation of dose in prey based on surface water and sediment data and dietary exposure models	• HQ_N based on the maximum concentrations was > 1.0 for Al, Ba, Pb, Hg, V, and Zn indicating potential risk to omnivorous aquatic amphibian species.

Notes: EQ_{max} – Ecological Quotients based on the maximum abiotic concentration; HQ_N – Hazard Quotient based on the No Observed Adverse Effect Level.

Appendix A: Summary of Analytical Results

Table A-1. Summary of SJR main stem site surface water data including date ranges, number of samples, media type, and ratio of detections to total samples for each chemical.

Site ID	Site Name	Number of Unique Samples	Media	Date Range of Samples	Chemicals (Detections/Samples)
4952940	San Juan River above Lake Powell	2	Surface Water-Total	8/11/2015	Total Al (2/2)
					Total Sb (0/2)
					Total As (1/2)
					Total Ba (2/2)
					Total Cd (1/2)
					Total Ca (2/2)
					Total Cr (0/2)
					Total Co (1/2)
					Total Cu (1/2)
					Total Hardness, as CaCO3 (2/2)
					Total Fe (2/2)
					Total Pb (1/2)
					Total Mg (2/2)
					Total Mn (2/2)
					Total Mo (1/2)
					Total Ni (1/2)
					Total K (2/2)
					Total Se (0/2)
					Total Ag (0/2)
					Total Na (2/2)
					Total Tl (0/2)
					Total V (0/2)
					Total Zn (0/2)
4952942	San Juan River at Clay Hills	16	Surface Water-Dissolved	8/13/15-2/17/16	Dissolved Ag (5/16)
					Dissolved Al (15/16)
					Dissolved As (16/16)
					Dissolved Ba (16/16)
					Dissolved Be (4/16)
					Dissolved Ca (16/16)
					Dissolved Cd (0/16)
					Dissolved Co (15/16)
					Dissolved Cr (0/16)
					Dissolved Cu (16/16)
					Dissolved Fe (7/16)

					Dissolved Hardness-Metals (1/1)
					Dissolved Hg (0/16)
					Dissolved K (16/16)
					Dissolved Mg (16/16)
					Dissolved Mn (11/16)
					Dissolved Mo (16/16)
					Dissolved Na (16/16)
					Dissolved Ni (13/16)
					Dissolved Pb (6/16)
					Dissolved Sb (15/16)
					Dissolved Se (16/16)
					Dissolved Sr (1/1)
					Dissolved Tl (2/16)
					Dissolved V (15/16)
					Dissolved Zn (6/16)
4952942	San Juan River at Clay Hills	63	Surface Water-Total	8/13/15-2/17/17	Total Ag (16/20)
					Total Al (20/20)
					Total Alk-CaCO3 (16/16)
					Total As (19/19)
					Total Ba (20/20)
					Total Be (18/20)
					Total Ca (20/20)
					Total Cd (15/20)
					Total Cl (16/16)
					Total Co (18/19)
					Total CO2 (1/1)
					Total CO3 (1/1)
					Total CO3-CaCO3 (4/15)
					Total Cr (18/20)
					Total Cu (20/20)
					Total Fe (20/20)
					Total Hard-CaCO3 (23/23)
					Total HCO3 (1/1)
					Total HCO3-CaCO3 (15/15)
					Total Hg (15/20)

					Total K (20/20)
					Total Mg (20/20)
					Total Mn (20/20)
					Total Mo (18/20)
					Total Na (20/20)
					Total Ni (20/20)
					Total NO3_NO2_N (9/16)
					Total OH (1/1)
					Total Pb (20/20)
					Total pH (15/15)
					Total PO4_P (13/13)
					Total Sb (19/20)
					Total SC (13/13)
					Total Se (20/20)
					Total SO4 (16/16)
					Total Sr (1/1)
					Total TDS_ROE (14/14)
					Total Tl (17/20)
					Total TOC (4/4)
					Total TSS (16/16)
					Total Turb (1/1)
					Total V (20/20)
					Total Zn (20/20)
4953000	San Juan River at Mexican Hat US163 Crossing	52	Surface Water-Dissolved	8/8/15-7/25/16	Dissolved Ag (21/52)
					Dissolved Al (41/52)
					Dissolved As (32/52)
					Dissolved B (1/1)
					Dissolved Ba (32/52)
					Dissolved Be (14/52)
					Dissolved Ca (52/52)
					Dissolved Cd (4/52)
					Dissolved Co (29/52)
					Dissolved Cr (4/52)
					Dissolved Cu (48/52)
					Dissolved Fe (21/52)
					Dissolved Hardness-Metals (19/19)
					Dissolved Hg (5/52)

					Dissolved K (52/52)
					Dissolved Mg (52/52)
					Dissolved Mn (20/52)
					Dissolved Mo (48/52)
					Dissolved Na (52/52)
					Dissolved Ni (16/52)
					Dissolved Pb (19/52)
					Dissolved Sb (29/52)
					Dissolved Se (34/52)
					Dissolved Sr (27/27)
					Dissolved Tl (13/52)
					Dissolved V (30/52)
					Dissolved Zn (22/52)
4953000	San Juan River at Mexican Hat US163 Crossing	130	Surface Water-Total	8/8/15-7/25/16	Total Ag (29/56)
					Total Al (57/57)
					Total Alk-CaCO3 (54/54)
					Total As (53/57)
					Total Ba (55/57)
					Total Be (35/57)
					Total Ca (57/57)
					Total Cd (38/56)
					Total Cl (50/50)
					Total Co (33/56)
					Total CO2 (26/26)
					Total CO3 (26/26)
					Total CO3-CaCO3 (9/24)
					Total Cr (49/57)
					Total Cu (56/56)
					Total Fe (56/56)
					Total Hard-CaCO3 (46/46)
					Total HCO3 (26/26)
					Total HCO3-CaCO3 (24/24)
					Total Hg (23/56)
					Total K (57/57)
					Total Mg (57/57)
					Total Mn (56/56)

					Total Mo (45/57)
					Total Na (57/57)
					Total Ni (41/57)
					NO3_NO2_N (46/50)
					Total OH (26/26)
					Total Pb (54/55)
					Total pH (71/71)
					Total PO4_P (18/18)
					Total Sb (33/56)
					Total SC (50/50)
					Total Se (38/57)
					Total SO4 (50/50)
					Total Sr (27/27)
					Total TDS_ROE (49/49)
					Total Tl (36/57)
					Total TOC (2/2)
					Total TSS (50/50)
					Total Turb (26/26)
					Total V (37/57)
					Total Zn (53/56)
4953250	San Juan River at Sand Island	44	Surface Water-Dissolved	8/8/15-7/9/16	Dissolved Ag (12/44)
					Dissolved Al (35/44)
					Dissolved As (25/44)
					Dissolved Ba (26/44)
					Dissolved Be (10/44)
					Dissolved Ca (44/44)
					Dissolved Cd (2/44)
					Dissolved Co (22/44)
					Dissolved Cr (3/44)
					Dissolved Cu (37/44)
					Dissolved Fe (21/44)
					Dissolved Hard-Metals (18/18)
					Dissolved Hg (2/44)
					Dissolved K (44/44)
					Dissolved Mg (44/44)
					Dissolved Mn (18/44)
					Dissolved Mo (39/44)
					Dissolved Na (44/44)

					Dissolved Ni (13/44)
					Dissolved Pb (15/44)
					Dissolved Sb (23/44)
					Dissolved Se (27/44)
					Dissolved Sr (23/23)
					Dissolved Tl (7/44)
					Dissolved V (23/44)
					Dissolved Zn (18/44)
4953250	San Juan River at Sand Island	110	Surface Water-Total	8/8/15-7/9/16	Total Ag (28/53)
					Total Al (53/53)
					Total Alk-CaCO3 (53/53)
					Total As (51/53)
					Total Ba (48/53)
					Total Be (36/53)
					Total Ca (53/53)
					Total Cd (36/53)
					Total Cl (53/53)
					Total Co (33/53)
					Total CO2 (23/23)
					Total CO3 (23/23)
					Total CO3-CaCO3 (5/20)
					Total Cr (42/53)
					Total Cu (53/53)
					Total Fe (53/53)
					Total Hard-CaCO3 (41/41)
					Total HCO3 (23/23)
					Total HCO3-CaCO3 (21/21)
4953253	San Juan R @ Sand Island-Duplicate	23	Surface Water-Total	3/9/16 - 7/9/16	Total Ag (1/19)
					Total Al (1/19)
					Total Alk-CaCO3 (2/2)
					Total As (18/19)
					Total Ba (16/19)
					Total Be (3/19)
					Total Ca (19/19)
					Total Cd (13/19)

					Total Cl (19/19)
					Total Co (17/19)
					Total CO2 (19/19)
					Total CO3 (0/19)
					Total Cr (14/19)
					Total Cu (19/19)
					Total Fe (19/19)
					Total HCO3 (19/19)
					Total Hg (0/19)
					Total K (19/19)
					Total Mg (19/19)
					Total Mn (19/19)
					Total Mo (9/19)
					Total Na (19/19)
					Total Ni (6/19)
					NO3_NO2_N (19/19)
					Total OH (0/19)
					Total Pb (19/19)
					Total pH (20/20)
					Total Sb (0/19)
					Total SC (19/19)
					Total Se (15/19)
					Total SO4 (19/19)
					Total Sr (19/19)
					Total TDS_ROE (19/19)
					Total Tl (7/19)
					Total TSS (19/19)
					Total Turb (0/19)
					Total V (3/19)
					Total Zn (16/19)
4953253	San Juan R @ Sand Island-Duplicate	23	Surface Water-Dissolved	3/9/16 - 7/9/16	Dissolved Ag (0/19)
					Dissolved Al (0/19)
					Dissolved As (2/19)
					Dissolved Ba (3/19)
					Dissolved Be (0/19)
					Dissolved Ca (19/19)
					Dissolved Cd (0/19)
					Dissolved Co (0/19)
					Dissolved Cr (04/19)

					Dissolved Cu (12/19)
					Dissolved Fe (8/19)
					Hardness (14/14)
					Dissolved Hg (0/19)
					Dissolved K (19/19)
					Dissolved Mg (19/19)
					Dissolved Mn (4/19)
					Dissolved Mo (16/19)
					Dissolved Na (19/19)
					Dissolved Ni (2/19)
					Dissolved Pb (7/19)
					Dissolved Sb (0/19)
					Dissolved Se (3/19)
					Dissolved Sr (19/19)
					Dissolved Tl (3/19)
					Dissolved V (2/19)
					Dissolved Zn (2/19)
4953880	San Juan R @ McElmo Wash	22	Surface Water-Total	3/23/16 - 7/9/16	Total Ag (2/22)
					Total Al (22/22)
					Total Alk-CaCO3 (22/22)
					Total As (15/22)
					Total Ba (3/22)
					Total Be (3/22)
					Total Ca (22/22)
					Total Cd (6/22)
					Total Cl (22/22)
					Total Co (3/22)
					Total CO2 (22/22)
					Total CO3 (0/22)
					Total Cr (10/22)
					Total Cu (18/22)
					Total Fe (22/22)
					Hardness CaCO3 (1/1)
					Total HCO3 (21/21)
					Total Hg (1/22)
					Total K (22/22)
					Total Mg (22/22)
					Total Mn (22/229)

					Total Mo (22/22)
					Total Na (22/229)
					Total Ni (8/22)
					NO3_NO2_N (9/21)
					Total OH (21/21)
					Total Pb (22/22)
					Total pH (21/21)
					Total Sb (3/22)
					Total SC (21/21)
					Total Se (12/22)
					Total SO4 (21/21)
					Total Sr (22/22)
					Total TDS_ROE (21/21)
					Total Tl (5/21)
					Total TSS (21/21)
					Total Turb (2/21)
					Total V (3/22)
					Total Zn (6/22)
4953880	San Juan R @ McElmo Wash	22	Surface Water-Dissolved	3/23/16 - 7/9/16	Dissolved Ag (1/22)
					Dissolved Al (4/22)
					Dissolved As (10/22)
					Dissolved Ba (3/22)
					Dissolved Be (1/22)
					Dissolved Ca (22/22)
					Dissolved Cd (1/22)
					Dissolved Co (3/22)
					Dissolved Cr (1/22)
					Dissolved Cu (15/22)
					Dissolved Fe (4/22)
					Hardness (16/16)
					Dissolved Hg (1/22)
					Dissolved K (22/22)
					Dissolved Mg (22/22)
					Dissolved Mn (22/22)
					Dissolved Mo (22/22)
					Dissolved Na (22/22)
					Dissolved Ni (2/22)
					Dissolved Pb (14/22)
					Dissolved Sb (3/22)

					Dissolved Se (12/22)
					Dissolved Sr (22/22)
					Dissolved Tl (3/22)
					Dissolved V (3/22)
					Dissolved Zn (4/22)
4953990	San Juan R @ Town of Montezuma	123	Surface Water-Total	8/8/15-7/9/16	Total Ag (2/22)
					Total Al (22/22)
					Total Alk-CaCO3 (22/22)
					Total As (15/22)
					Total Ba (3/22)
					Total Be (3/22)
					Total Ca (22/22)
					Total Cd (6/22)
					Total Cl (22/22)
					Total Co (3/22)
					Total CO2 (22/22)
					Total CO3 (0/22)
					Total Cr (10/22)
					Total Cu (18/22)
					Total Fe (22/22)
					Hardness CaCO3 (1/1)
					Total HCO3 (21/21)
					Total Hg (1/22)
					Total K (22/22)
					Total Mg (22/22)
					Total Mn (22/229)
					Total Mo (22/22)
					Total Na (22/229)
					Total Ni (8/22)
					NO3_NO2_N (9/21)
					Total OH (21/21)
					Total Pb (22/22)
					Total pH (21/21)
					Total PO4_P (22/22)
					Total Sb (3/22)
					Total SC (21/21)
					Total Se (12/22)
					Total SO4 (21/21)

					Total Sr (22/22)
					Total TDS_ROE (21/21)
					Total Tl (5/21)
					TOC (2/2)
					Total TSS (21/21)
					Total Turb (2/21)
					Total V (3/22)
					Total Zn (6/22)
4953990	San Juan River at Town of Montezuma	46	Surface Water-Dissolved	8/8/15-7/9/16	Dissolved Ag (14/46)
					Dissolved Al (36/46)
					Dissolved As (25/46)
					Dissolved Ba (30/46)
					Dissolved Be (13/46)
					Dissolved Ca (46/46)
					Dissolved Cd (3/46)
					Dissolved Co (24/46)
					Dissolved Cr (2/46)
					Dissolved Cu (40/46)
					Dissolved Fe (19/46)
					Dissolved Hard-Metals (18/18)
					Dissolved Hg (2/46)
					Dissolved K (46/46)
					Dissolved Mg (46/46)
					Dissolved Mn (24/46)
					Dissolved Mo (41/46)
					Dissolved Na (46/46)
					Dissolved Ni (13/46)
					Dissolved Pb (18/46)
					Dissolved Sb (25/46)
					Dissolved Se (28/46)
					Dissolved Sr (23/23)
					Dissolved Tl (7/46)
					Dissolved V (24/46)
					Dissolved Zn (21/46)
4954000	San Juan River at US160 Crossing in	112	Surface Water Total	8/8/15-7/9/16	Total Ag (35/58)
					Total Al (58/58)
					Total Alk-CaCO3 (48/48)

	Colorado				Total As (54/58)
					Total Ba (54/58)
					Total Be (40/58)
					Total Ca (58/58)
					Total Cd (45/58)
					Total Cl (58/58)
					Total Co (38/58)
					Total CO2 (22/22)
					Total CO3 (22/22)
					Total CO3-CaCO3 (6/24)
					Total Cr (47/58)
					Total Cu (58/58)
					Total Fe (58/58)
					Total Hard-CaCO3 (46/46)
					Total HCO3 (22/22)
					Total HCO3-CaCO3 (24/24)
					Total Hg (31/58)
					Total K (58/58)
					Total Mg (58/58)
					Total Mn (58/58)
					Total Mo (41/58)
					Total Na (58/58)
					Total Ni (42/58)
					Total NO3_NO2_N (41/44)
					Total OH (21/21)
					Total Pb (58/58)
					Total pH (64/64)
					Total PO4_P (13/15)
					Total Sb (36/58)
					Total SC (58/58)
					Total Se (39/58)
					Total SO4 (45/45)
					Total Sr (23/23)
					Total TDS_ROE (45/45)
					Total Tl (34/58)

					Total TSS (46/46)
					Total Turb (22/22)
					Total V (39/58)
					Total Zn (55/58)
4954000	San Juan River at US160 Crossing in Colorado	45	Surface Water Dissolved	8/8/15-7/9/16	Dissolved Ag (12/45)
					Dissolved Al (37/45)
					Dissolved As (24/45)
					Dissolved Ba (28/45)
					Dissolved Be (13/45)
					Dissolved Ca (45/45)
					Dissolved Cd (3/45)
					Dissolved Co (22/45)
					Dissolved Cr (3/45)
					Dissolved Cu (40/45)
					Dissolved Fe (22/45)
					Dissolved Hard-Metals (17/17)
					Dissolved Hg (4/45)
					Dissolved K (45/45)
					Dissolved Mg (45/45)
					Dissolved Mn (27/45)
					Dissolved Mo (39/45)
					Dissolved Na (45/45)
					Dissolved Ni (10/45)
					Dissolved Pb (21/45)
					Dissolved Sb (24/45)
					Dissolved Se (27/45)
					Dissolved Sr (23/45)
					Dissolved Tl (7/45)
					Dissolved V (24/45)
					Dissolved Zn (24/45)

Table A-2. Summary of SJR main stem site sediment data including date ranges, number of samples, media type, and ratio of detections to total samples for each chemical.

Site ID	Site Name	Number of Unique Samples	Media	Date Range of Samples	Chemicals (Detections/Samples)
4952942	San Juan River at Clay Hills	7	Sediment	8/15/15-2/17/16	Total Ag (2/7)
					Total Al (7/7)
					Total As (7/7)
					Total Ba (7/7)
					Total Be (7/7)
					Total Ca (7/7)
					Total Cd (6/7)
					Total Co (7/7)
					Total Cr (7/7)
					Total Cu (6/7)
					Total Fe (7/7)
					Total Hard-CaCO3 (3/3)
					Total Hg (4/7)
					Total K (7/7)
					Total Mg (7/7)
					Total Mn (7/7)
					Total Mo (0/7)
					Total Na(7/7)
					Total Ni (6/7)
					Total Pb (5/7)
					Total Perc_Moist (6/7)
					Total Sb (0/7)
					Total Se (6/7)
					Total Tl (6/7)
					Total V (7/7)
					Total Zn (7/7)
4953000	San Juan River at Mexican Hat US163 Crossing	4	Sediment	9/22/15-2/17/16	Total Ag (0/4)
					Total Al (4/4)
					Total As (4/4)
					Total Ba (4/4)
					Total Be (3/4)
					Total Ca (4/4)

					Total Cd (3/4)
					Total Cr (4/4)
					Total Cu (4/4)
					Total Fe (4/4)
					Total Hg (3/4)
					Total K (4/4)
					Total Mg (4/4)
					Total Mn (4/4)
					Total Mo (0/4)
					Total Na (4/4)
					Total Ni (4/4)
					Total Pb (3/4)
					Total Perc_Moist (3/3)
					Total Sb (0/4)
					Total Se (1/4)
					Total Sr (1/1)
					Total Tl (3/4)
					Total V (4/4)
					Total Zn (4/4)
4953250	San Juan River at Sand Island	1	Sediment	2/16/2016	Total Ag (0/1)
					Total Al (1/1)
					Total As (1/1)
					Total Ba (1/7)
					Total Be (0/1)
					Total Ca (1/1)
					Total Cd (0/1)
					Total Co (1/1))
					Total Cr (1/1)
					Total Cu (1/1)
					Total Fe (1/1)
					Total Hg (0/1)
					Total K (1/1)
					Total Mg (1/1)
					Total Mn (1/1)
					Total Mo (0/1)
					Total Na (1/1)
					Total Ni (1/1)
					Total Pb (1/1)
					Total Sb (0/1)

					Total Se (1/1)
					Total Sr (1/1)
					Total Tl (0/1)
					Total V (1/1)
					Total Zn (1/1)
4953990	San Juan River at Town of Montezuma	5	Sediment	8/15/15-2/16/16	Total Ag (3/5)
					Total Al (5/5)
					Total As (5/5)
					Total Ba (5/5)
					Total Be (5/5)
					Total Ca (5/5)
					Total Cd (5/5)
					Total Co (5/5)
					Total Cr (5/5)
					Total Cu (5/5)
					Total Fe (5/5)
					Total Hard-CaCO3 (2/2)
					Total Hg (3/5)
					Total K (5/5)
					Total Mg (5/5)
					Total Mn (5/5)
					Total Mo (2/5)
					Total Na (5/5)
					Total Ni (5/5)
					Total Pb (5/5)
					Total Perc_Moist (4/4)
					Total Sb (0/5)
					Total Se (1/5)
					Total Sr (1/1)
					Total Tl (4/5)
					Total V (5/5)
					Total Zn (5/5)
4954000	San Juan River at US160 Crossing in Colorado	8	Sediment	8/8/15-2/16/16	Total Ag (6/8)
					Total Al (8/8)
					Total As (8/8)
					Total Ba (8/8)
					Total Be (7/8)
					Total Ca (8/8)

					Total Cd (7/8)
					Total Co (8/8)
					Total Cr (8/8)
					Total Cu (8/8)
					Total Fe (8/8)
					Total Hard-CaCO3 (6/6)
					Total Hg (7/8)
					Total K (8/8)
					Total Mg (8/8)
					Total Mn (8/8)
					Total Mo (3/8)
					Total Na (8/8)
					Total Ni (8/8)
					Total Pb (8/8)
					Total Perc_Moist (7/7)
					Total Sb (0/8)
					Total Se (0/8)
					Total Sr (1/1)
					Total Tl (7/8)
					Total V (8/8)
					Total Zn (8/8)

Table A-3. Summary of SJR main stem site surface water data including ranges of sample quantitation limits, ranges of detections, and location of maximum detected concentration.

Analyte	Frequency of Detection (1)	Range of Sample Quantitation Limits (SQLs)				Range of Detections				Location (Sample ID) of Maximum Detected Concentration
		Min.	Q	Max	Q	Min.	Q	Max	Q	
Inorganics (ug/L)										
Aluminum total	288/288	--	--	--	--	15.659	-	248000	-	4954000
Aluminum dissolved	185/246	10	U	100	U	10	J	20700	-	4954000
Antimony total	160/288	0.002	U	5	U	0.0727	J B	6	U	4953000
Antimony dissolved	121/246	2	U	3	U	0.0516	J	3.458	-	4953990
Arsenic total	264/288	1	U	2	U	1.009	-	45	-	4953000
Arsenic dissolved	135/246	1	U	2	U	0.628	J	5.55	-	4954000
Barium total	249/287	0.1	U	0.1	U	0.0523	-	20000	J	4953000
Barium dissolved	140/247	100	U	100	U	42.9	-	451	-	4954000
Beryllium total	176/288	1	U	5	U	0.101	J	53.3	-	4954000
Beryllium dissolved	58/246	1	U	2	U	0.0299	J	1.58	J	4954000
Bicarbonate total	135/135	--	--	--	--	84	-	314	-	4953880
Bicarbonate-calcium carbonate total	106/106	--	--	--	U	87.9	-	1110	-	4953250
Cadmium total	194/288	0.5	U	1	U	0.1	J	24.9	-	4954000
Cadmium dissolved	16/246	0.1	U	0.5	U	0.1	J	0.303	J	4953990
Calcium total	288/288	--	--	--	--	32.8	J	4230	J	4952942
Calcium dissolved	246/246	--	--	--	--	30.8	-	272	-	4953880
Chloride total	241/241	--	--	--	--	3.63	-	55.6	-	4953880
Chromium total	226/288	2	U	2.5	U	1.62	J	123	-	4954000
Chromium dissolved	16/246	2	U	2	U	2	-	12	-	4954000
Carbon dioxide total	135/135	--	--	--	--	3	-	78	-	4953250
Carbonate total	135/135	-	--	--	--	0	-	0	-	4953560
Carbonate-calcium carbonate total	30/106	1.86	U	10	U	3.4	J	23.7	-	4952942
Cobalt total	166/288	4	U	30	U	0.588	J	254	-	4954000
Cobalt dissolved	117/246	4	U	30	U	0.0455	J	30	U	4953990
Copper total	282/288	1	U	5	U	1.053	-	333	-	4954000
Copper dissolved	209/246	0.02	U	1	U	1	-	27.7	B	4954000
Hardness-calcium carbonate total	209/209	--	--	--	--	120	-	10000	-	4952940
hardness-metals dissolved	103/103	--	--	--	--	98.4	-	1423.4	-	4953880

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Iron total	287/288	0.1	U	0.1	U	0.0222	-	181	-	4954000
Iron dissolved	101/246	0.1	U	20	U	20	-	16700	-	4954000
Lead total	284/288	0.002	U	0.002	U	0.00012	-	0.369	B	4954000
Lead dissolved	94/246	0.1	U	2	U	0.1	-	15.7	-	4954000
Magnesium total	288/288	--	--	--	--	5.39	-	478	-	4953990
Magnesium dissolved	246/246	--	--	--	--	4.98	-	181	-	4953880
Manganese total	288/288	--	--	--	--	0.0147	-	39.5	-	4952940
Manganese dissolved	126/246	2	U	5	U	1.55	J	413	-	4954000
Mercury total	126/286	0.00015	U	0.2	U	0.00001	J	0.00177	-	4952942
Mercury dissolved	17/246	0.00015	U	0.2	U	0.00001	J	0.0000383	J	4954000
Molybdenum dissolved	220/243	0.002	U	1	U	0.001002	-	0.010694	-	4953000
Molybdenum total	218/288	0.02	U	5	U	0.000234	J	0.0159	-	4952942
Nickel total	198/288	0.002	U	5	U	0.00119	J	0.375	-	4954000
Nickel dissolved	69/246	0.002	U	5	U	0.756	J	12.7	-	4954000
Nitrate-nitrite-nitrogen total	208/241	0.01	U	0.1	U	0.0125	-	46.4	-	4954000
pH total	358/358	--	--	--	--	6.415	-	9.67	-	4953250
Phosphate-phosphorus total	74/78	0.05	U	0.05	U	0.025	-	11.5	-	4952942
Potassium total	288/288	--	--	--	--	1.718	-	48.5	-	4954000
Potassium dissolved	246/246	--	--	--	--	1.59	-	7.89	-	4954000
Selenium total	143/242	0.002	U	2.5	U	0.000476	J	0.032986	-	4953000
Selenium dissolved	147/246	1	U	2	U	0.504	J	2.97	-	4953000
Silver total	144/288	0.25	U	5	U	0.0000259	J B	0.00671	-	4954000
Silver dissolved	68/178	0.5	U	2	U	0.0249	J	0.5	U	4953990
Sodium total	288/288	--	--	--	--	10.9	-	463	-	4953560
Sodium dissolved	246/246	--	--	--	--	0.0534	-	512.7	-	4953560
Specific conductance total	237/237	--	--	--	--	248	-	3040	-	4953560
Strontium total	140/140	--	--	--	--	0.843	-	3.91	-	4953880
Strontium dissolved	138/138	--	--	--	--	0.816	-	3.66	-	4953880
Sulfate total	241/241	--	--	--	--	45	-	1570	-	4953880
TDS_ROE total	237/237	--	--	--	--	152	-	2562	-	4953880
Thallium dissolved	41/243	0.002	U	0.1	U	0.000025	J	0.000282	-	4953000
Thallium total	166/288	0.002	U	1	U	0.0000303	J	0.00259	-	4954000
TOC total	8/8	--	--	--	--	2.85	-	5.04	-	4952942
TSS total	241/241	--	--	--	--	10.8	-	59300	-	4952942
Turbidity total	135/135		U		U	0		1		4953000, 4953250, 4953253, 4953880, 4954000, 4953990
Vanadium total	174/288	0.005	U	30	U	0	J	0.178	J	4954000
Vanadium dissolved	120/243	0.005	U	30	U	0	-	0.262	-	4954000

Zinc total	255/288	0.005	U	50	U	0	-	1.25	-	4954000
Zinc dissolved	98/246	5	U	10	U	4.78	J	191	-	4953990

NOTES:

(1) Frequency of Detection
Rules:
- Does not include field, rinsate
or trip blanks
- Includes the maximum of the duplicate
samples.

Table A-4. Summary of SJR main stem site sediment data including ranges of sample quantitation limits, ranges of detections, and location of maximum detected concentration.

Analyte	Frequency of Detection (1)	Range of Sample Quantitation Limits (SQLs)				Range of Detections				Location (Sample ID) of Maximum Detected Concentration
		Min.	Q	Max	Q	Min.	Q	Max	Q	
Inorganics (mg/kg)										
Ag	11/25	0.4	U	1.74	U	0.0243	J	0.0778	J	4952942
Al	25/25	--	--	--	--	2720	B	16200	B	4954000
As	25/25	--	--	--	--	1.1	J	3.37	-	4954000
Ba	25/25	--	--	--	--	135.9	-	564	-	4954000
Be	22/25	0.4	U	0.5	U	0.162	J	0.627	J	4954000
Ca	25/25	--	--	--	--	4610	B	29479	-	4952942
Cd	21/25	0.1	--	0.1	--	0.0648	J	0.254	J	4954000
Co	25/25	--	--	--	--	1.41	-	4.7	-	4953990
Cr	25/25	--	--	--	--	2.32	J	15.3	-	4952942
Cu	24/25	1.49		1.49		1.85	J	9.9	J	4954000
Fe	25/25	--	--	--	--	3760	B	12100	B	4953990
Hg	18/25	0.0486	U	0.06	U	0.0019	JB	0.0228	J	4954000
K	25/25	--	--	--	--	535	-	5080	-	4953990
Mg	25/25	--	--	--	--	1350	B	6580	-	4952942
Mn	25/25	--	--	--	--	132	-	279.7	-	4953990
Mo	5/25	0.4	U	23.2	U	0.355	J	0.578	J	4953990
Na	25/25	--	--	--	--	113	J	517	B	4953990
Ni	24/25	2.12	U	2.12	U	2.15	J	11.1	-	4952942
Pb	22/25	3.32	U	4.02	U	2.99	J	9.6	-	4953990
Sb	0/25	0.4	U	4.63	U	--	--	--	--	--
Se	5/25	0.484	U	0.632	U	2.1	--	3.8	--	4953990
Sr	5/5	-		-		74.2	-	133.1	-	4952942
Tl	20/25	0.1	--	0.1	--	0.0334	J	0.172	J	4954000
V	25/25	--	--	--	--	6.74	J	28.1	-	4954000
Zn	25/25	--	--	--	--	10.4	J	34.3	J	4954000

NOTES:

(1) Frequency of Detection Rules:
- Does not include field, rinsate or trip blanks
- Includes the maximum of the duplicate samples.

Appendix B: Step 2 Post-GKM Spill Aquatic Risk Assessment

Table B-1. Summary of mammalian toxicity studies used to determine body-weight normalized TRVs for risk determination.

Chemical	Test Organism	Body Weight (kg)	Duration	Exposure Route	Effect/Endpoint	LOAEL (mg/kg/d)	NOAEL (mg/kg/d)	Reference
Aluminum	mouse	0.03	3 generations	oral in water	reproduction	19.3	1.93	Sample et al. 1996
Aluminum	rat	0.435	16 months	oral in water	growth/hypertension	5.1	5.1	Sample et al. 1996
Barium	rat	0.35	10 days	oral (gavage) in water	mortality	>19.8	19.8	Sample et al. 1996
Beryllium	rat	0.15	75 days	oral	histology	0.478	<0.478	From ECO-SSL in Goel et al, 1980
Cobalt	rat	0.00021	69 days	oral in diet	reproduction	20	5	From ECO-SSL in Nation et al., 1983
Copper	mouse	0.03	1 month + GD 0-19	oral in diet	developmental	104	78	ATSDR 1990a
Copper	mink	1	357 days	oral in diet	reproduction	15.1	11.7	Sample et al. 1996
Iron	NA	NA	NA	NA	NA	NA	NA	NA
Lead	rat	0.35	3 generations	oral in diet	reproduction	80	8	Sample et al. 1996
Manganese	rat	0.35	224 days	oral in diet	reproduction	284	88	Sample et al. 1996
Mercury	mouse	0.03	20 months	oral in diet	reproduction	66	13.2	Sample et al. 1996
Mercury	mink	1	6 months	oral in diet	reproduction	5	1	Sample et al. 1996
Nitrate-Nitrite-Nitrogen	Guinea pig	0.86	143 - 204 days	oral in water	reproduction	1130	507	Sample et al. 1996
Silver	rat	0.35	2 weeks	oral in water	survival	45.3	9.06	ATSDR 1990b
Strontium	rat	0.35	3 years	oral in water	body weight and bone changes	>263	263	Sample et al. 1996
Vanadium	rat	0.26	60 d	oral intubation	reproduction	2.1	0.21	Sample et al. 1996
Zinc	rat	0.35	GD 1-16	oral in diet	reproduction	320	160	Sample et al. 1996
Zinc	mink	1	25 weeks	oral	reproduction	104	20.8	ATSDR 1994

Notes:
kg = kilogram
mg/kg/d = milograms/kilograms/day
LOAEL = Lowest Observed Adverse Effect Level
NOAEL = No Observed Adverse Effect Level
GD = gestation days

Table B-2. Summary of avian toxicity studies used to determine body-weight normalized TRVs for risk determination.

Chemical	Test Organism	Body Weight (kg)	Duration	Exposure Route	Effect/Endpoint	LOAEL (mg/kg/d)	NOAEL (mg/kg/d)	Reference
Aluminum	ringed dove	0.155	4 months	oral in diet	reproduction	>109.7	109.7	Sample et al. 1996
Barium	chicks	0.121	4 weeks	oral in diet	mortality	41.7	20.8	Sample et al. 1996
Beryllium	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	chicken	0.33	5 weeks	oral in diet	growth	7.8	3.89	From ECO-SSL in Hill, 1979
Copper	chicks	0.53	10 weeks	oral in diet	growth/survival	61.7	47	Sample et al. 1996
Iron	NA	NA	NA	NA	NA	NA	NA	NA
Lead	Japanese quail	0.15	12 weeks	oral in diet	reproduction	11.3	1.13	Sample et al. 1996
Lead	American kestrel	0.13	7 months	oral in diet	reproduction	0.9	0.45	Sample et al. 1996
Manganese	Japanese quail	0.072	75 days	oral in diet	growth	>977	977	Sample et al. 1996
Mercury	Japanese quail	0.15	1 year	oral in diet	reproduction	0.9	0.45	Sample et al. 1996
Mercury	red-tailed hawk	1.1	12 weeks	oral in diet	survival/neurological	1.2	0.49	USEPA 1995c
Mercury	mallard	1	3 generations	oral in diet	reproduction	0.078	0.026	USEPA 1997
Nitrate-Nitrite-Nitrogen	NA	NA	NA	NA	NA	NA	NA	NA
Silver	mallard	1.1	14 days	oral in diet	survival	178	35.6	USEPA 1999b
Silver	chicken (chicks)	0.8	not specified	oral in diet	growth	35	7	Eisler 1996
Strontium	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	mallard	1.17	12 weeks	oral in diet	mortality, body weight	>11.4	11.4	Sample et al. 1996
Zinc	chicken	1.94	44 weeks	oral in diet	reproduction	131	14.5	Sample et al. 1996

Notes:
kg = kilogram
mg/kg/d = milograms/kilograms/day
LOAEL = Lowest Observed Adverse Effect Level
NOAEL = No Observed Adverse Effect Level
GD = gestation days

Table B-3. Summary of measured concentrations in sediment and surface water and calculated concentrations of benthic invertebrates, plants, and fish tissue used in the post-GKM spill risk assessment.

Chemical	Sediment Maximum Concentration (mg/kg)	Water Maximum Concentration (mg/L)	Benthic Invertebrate Concentration (mg/kg)	Plant Concentration (mg/kg)	Fish Concentration (mg/kg)
Aluminum	16200	20.7	19213.2	16200	16774.65
Barium	564	0.451	668.904	84.6	867.54
Beryllium	0.627	0.00158	0.743622	0.009439089	0.75
Cobalt	4.36	0.03	5.17096	0.0327	4.53
Copper	9.9	0.0277	23.0274966	3.873677054	80.28
Iron	12100	16.7	14350.6	12100	12504.17
Lead	9.6	0.0157	1.337898341	0.167129903	10.76
Manganese	279.7	0.413	331.7242	22.0963	289.07
Mercury	0.0228	0.0002	0.0270408	0.013826637	2.90
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	NA	46.40
Silver	0.0778	0.0005	0.014004	0.0010892	0.13
Strontium	133.1	4.57	157.8566	133.1	411.56
Vanadium	28.1	0.03	33.3266	0.136285	0.93
Zinc	34.3	0.191	121.1844955	266.4114845	496.51

Table B-4. Detailed raccoon risk analysis for post-GKM spill maximum concentration.

Raccoon

Food Ingestion Rate	0.0500000 kg dw/kg bw/day
Water Ingestion Rate	0.1670000 L/kg bw/day
Sediment Ingestion Rate	0.0047000 kg dw/kg bw/day
Area Use Factor	1.0000000

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Invertebrate Concentration (mg/kg)	Plant Concentration (mg/kg)	Fish Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	19213.2	16200	16774.65	960.66000	76.14000	3.46	1040.257	0.58	5.80	1792.54	179.25
Barium	564	0.451	668.904	84.6	867.54	43.37717	2.65080	0.08	46.103	2.99	<2.99	15.41	<15.4
Beryllium	0.627	0.00158	0.743622	0.009439089	0.75	0.03725	0.00295	0.00	0.040	<0.21	0.21	>0.19	0.19
Cobalt	4.36	0.03	5.17096	0.0327	4.53	0.25855	0.02049	0.01	0.284	0.43	1.74	0.65	0.163
Copper	9.9	0.0277	23.0274966	3.873677054	80.28	4.01399	0.04653	0.00	4.065	8.45	10.91	0.48	0.37
Iron	12100	16.7	14350.6	12100	12504.17	717.53000	56.87000	2.79	777.189	NA	NA	NA	NA
Lead	9.6	0.0157	1.337898341	0.167129903	10.76	0.53781	0.04512	0.00	0.586	4.45	44.46	0.13	0.01
Manganese	279.7	0.413	331.7242	22.0963	289.07	16.58621	1.31459	0.07	17.970	48.90	157.82	0.367	0.114
Mercury	0.0228	0.0002	0.0270408	0.013826637	2.90	0.14494	0.00011	0.00	0.145	0.72	3.61	0.20	0.04
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	NA	46.40	2.32000	NA	7.75	10.069	352.75	786.21	0.02854	0.01281
Silver	0.0778	0.0005	0.014004	0.0010892	0.13	0.00671	0.00037	0.00	0.007	5.03	25.17	0.001	0.0003
Strontium	133.1	4.57	157.8566	133.1	411.56	20.57811	0.62557	0.76	21.967	146.15	>146.15	0.15	<0.2
Vanadium	28.1	0.03	33.3266	0.136285	0.93	1.66633	0.13207	0.01	1.803	0.11	1.08	16.65	1.66
Zinc	34.3	0.191	121.1844955	266.4114845	496.51	24.82550	0.16121	0.03	25.019	15.0278489	75.14	1.66	0.33

NA = Not Available, HQ_n = Hazard Quotient based on the NOAEL, HQ_l = Hazard Quotient based on the LOAEL

Foodweb Model Calculations:

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-5. Detailed muskrat risk analysis for post-GKM spill maximum concentration.

Muskrat

Food Ingestion Rate	0.1030000 kg dw/kg bw/day
Water Ingestion Rate	0.1750000 L/kg bw/day
Sediment Ingestion Rate	0.0097000 kg dw/kg bw/day
Area Use Factor	1.0000000

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Invertebrate Concentration (mg/kg)	Plant Concentration (mg/kg)	Fish Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	19213.2	16200	16774.65	1978.95960	157.14	3.62	2139.722	0.84	8.40	2548.01	254.80
Barium	564	0.451	668.904	84.6	867.54	89.35697	5.47	0.08	94.907	4.33	<4.33	21.92	<21.9
Beryllium	0.627	0.00158	0.743622	0.009439089	0.75	0.07674	0.01	0.00	0.083	<0.31	0.31	NA	0.27
Cobalt	4.36	0.03	5.17096	0.0327	4.53	0.53261	0.04	0.01	0.580	0.63	2.52	0.92	0.230
Copper	9.9	0.0277	23.0274966	3.873677054	80.28	8.26881	0.10	0.00	8.370	33.94	45.25	0.25	0.18
Iron	12100	16.7	14350.6	12100	12504.17	1478.11180	117.37	2.92	1598.404	NA	NA	NA	NA
Lead	9.6	0.0157	1.337898341	0.167129903	10.76	1.10788	0.09	0.00	1.204	6.43	64.33	0.19	0.02
Manganese	279.7	0.413	331.7242	22.0963	289.07	34.16759	2.71	0.07	36.953	70.76	228.38	0.522	0.162
Mercury	0.0228	0.0002	0.0270408	0.013826637	2.90	0.29858	0.00	0.00	0.299	5.74	28.72	0.05	0.01
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	NA	46.40	4.77920	NA	8.12	12.899	510.45	1137.68	0.02527	0.01134
Silver	0.0778	0.0005	0.014004	0.0010892	0.13	0.01382	0.00	0.00	0.015	7.29	36.43	0.002	0.0004
Strontium	133.1	4.57	157.8566	133.1	411.56	42.39090	1.29	0.80	44.482	211.49	>211.49	0.21	<0.2
Vanadium	28.1	0.03	33.3266	0.136285	0.93	3.43264	0.27	0.01	3.710	0.16	1.57	23.67	2.37
Zinc	34.3	0.191	121.1844955	266.4114845	496.51	51.14054	0.33	0.03	51.507	128.66	257.33	0.40	0.20

NA = Not Available, HQ_n = Hazard Quotient based on the NOAEL, HQ_l = Hazard Quotient based on the LOAEL

Foodweb Model Calculations:

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-6. Detailed mink risk analysis for post-GKM spill maximum concentration.

Mink

Food Ingestion Rate	0.1830000 kg dw/kg bw/day
Water Ingestion Rate	0.3930000 L/kg bw/day
Sediment Ingestion Rate	0.0037000 kg dw/kg bw/day
Area Use Factor	1.0000000

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Invertebrate Concentration (mg/kg)	Plant Concentration (mg/kg)	Fish Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	19213.2	16200	16774.65	3516.01560	59.94	8.14	3584.091	0.94	9.40	3812.62	381.26
Barium	564	0.451	668.904	84.6	867.54	158.76044	2.09	0.18	161.024	4.85	<4.85	33.22	<33.2
Beryllium	0.627	0.00158	0.743622	0.009439089	0.75	0.13634	0.00	0.00	0.139	<0.35	0.35	NA	0.40
Cobalt	4.36	0.03	5.17096	0.0327	4.53	0.94629	0.02	0.01	0.974	0.70	2.82	1.38	0.346
Copper	9.9	0.0277	23.0274966	3.873677054	80.28	14.69119	0.04	0.01	14.739	13.69	17.67	1.08	0.83
Iron	12100	16.7	14350.6	12100	12504.17	2626.15980	44.77	6.56	2677.493	NA	NA	NA	NA
Lead	9.6	0.0157	1.337898341	0.167129903	10.76	1.96837	0.04	0.01	2.010	7.20	72.02	0.28	0.03
Manganese	279.7	0.413	331.7242	22.0963	289.07	60.70553	1.03	0.16	61.903	79.22	255.65	0.7814	0.2421
Mercury	0.0228	0.0002	0.0270408	0.013826637	2.90	0.53049	0.00	0.00	0.531	1.17	5.85	0.45	0.09
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	NA	46.40	8.49120	NA	18.24	26.726	571.41	1273.57	0.04677	0.02099
Silver	0.0778	0.0005	0.014004	0.0010892	0.13	0.02455	0.00	0.00	0.025	8.16	40.78	0.0031	0.0006
Strontium	133.1	4.57	157.8566	133.1	411.56	75.31587	0.49	1.80	77.604	236.75	>236.75	0.33	<0.3
Vanadium	28.1	0.03	33.3266	0.136285	0.93	6.09877	0.10	0.01	6.215	0.18	1.76	35.41	3.541
Zinc	34.3	0.191	121.1844955	266.4114845	496.51	90.86134	0.13	0.08	91.063	24.3434167	121.71708	3.74	0.75

NA = Not Available, HQ_n = Hazard Quotient based on the NOAEL, HQ_l = Hazard Quotient based on the LOAEL

Foodweb Model Calculations:

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-7. Detailed mallard risk analysis for post-GKM spill maximum concentration.

Mallard

Food Ingestion Rate	0.0590000 kg dw/kg bw/day
Water Ingestion Rate	0.0690000 L/kg bw/day
Sediment Ingestion Rate	0.0020000 kg dw/kg bw/day
Area Use Factor	1.0000000

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Invertebrate Concentration (mg/kg)	Plant Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	19213.2	16200	1133.57880	955.80	1.43	2090.807	109.7	>109.7	19.06	<19.1
Barium	564	0.451	668.904	84.6	39.46534	33.28	0.03	72.772	20.8	41.7	3.4987	1.7451
Beryllium	0.627	0.00158	0.743622	0.009439089	0.04387	0.04	0.00	0.081	NA	NA	NA	NA
Cobalt	4.36	0.03	5.17096	0.0327	0.30509	0.26	0.00	0.564	3.89	7.8	0.1451	0.0724
Copper	9.9	0.0277	23.0274966	3.873677054	1.35862	0.58	0.00	1.945	47	61.7	0.04138	0.03152
Iron	12100	16.7	14350.6	12100	846.68540	713.90	1.15	1561.738	NA	NA	NA	NA
Lead	9.6	0.0157	1.337898341	0.167129903	0.07894	0.57	0.00	0.646	1.13	11.3	0.57205	0.05721
Manganese	279.7	0.413	331.7242	22.0963	19.57173	16.50	0.03	36.103	977	>977	0.03695	<0.04
Mercury	0.0228	0.0002	0.0270408	0.013826637	0.00160	0.00	0.00	0.003	0.026	0.078	0.11363	0.03788
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	NA	NA	NA	3.20	3.202	NA	NA	NA	NA
Silver	0.0778	0.0005	0.014004	0.0010892	0.00083	0.00	0.00	0.005	7	35	0.0007787	0.0001557
Strontium	133.1	4.57	157.8566	133.1	9.31354	7.85	0.32	17.482	NA	NA	NA	NA
Vanadium	28.1	0.03	33.3266	0.136285	1.96627	1.66	0.00	3.626	11.4	>11.4	0.3181	<0.32
Zinc	34.3	0.191	121.1844955	266.4114845	15.71828	2.02	0.01318	17.755	14.5	131	1.2245	0.1355

NA = Not Available, HQn = Hazard Quotient based on the NOAEL, HQl = Hazard Quotient based on the LOAEL

<u>Foodweb Model Calculations:</u>

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-8. Detailed belted kingfisher risk analysis for post-GKM spill maximum concentration.

Belted Kingfisher

Food Ingestion Rate	0.0970000 kg dw/kg bw/day
Water Ingestion Rate	0.0700000 L/kg bw/day
Sediment Ingestion Rate	0.0000000 kg dw/kg bw/day
Area Use Factor	1.0000000

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Invertebrate Concentration (mg/kg)	Fish Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	19213.2	16774.65	1863.68040	0.00000	1.45	1865.13	109.7	>109.7	17.00	<17
Barium	564	0.451	668.904	867.54	84.15171	0.00000	0.03	84.18	20.8	41.7	4.05	2.02
Beryllium	0.627	0.00158	0.743622	0.75	0.07227	0.00000	0.00	0.07	NA	NA	NA	NA
Cobalt	4.36	0.03	5.17096	4.53	0.50158	0.00000	0.00	0.50	3.89	7.8	0.129	0.065
Copper	9.9	0.0277	23.0274966	80.28	7.78714	0.00000	0.00	7.79	47	61.7	0.17	0.13
Iron	12100	16.7	14350.6	12504.17	1392.00820	0.00000	1.17	1393.18	NA	NA	NA	NA
Lead	9.6	0.0157	1.337898341	10.76	1.04334	0.00000	0.00	1.04	0.45	11.3	2.32	0.09
Manganese	279.7	0.413	331.7242	289.07	32.17725	0.00000	0.03	32.21	977	>977	0.0330	<0.03
Mercury	0.0228	0.0002	0.0270408	2.90	0.28119	0.00000	0.00	0.28	0.49	1.2	0.57	0.23
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	46.40	4.50080	NA	3.25	7.75	NA	NA	NA	NA
Silver	0.0778	0.0005	0.014004	0.13	0.01302	0.00000	0.00	0.01	7	35	0.0019	0.0004
Strontium	133.1	4.57	157.8566	411.56	39.92153	0.00000	0.32	40.24	NA	NA	NA	NA
Vanadium	28.1	0.03	33.3266	0.93	3.23268	0.00000	0.00	3.23	11.4	>11.4	0.284	<0.3
Zinc	34.3	0.191	121.1844955	496.51	48.16148	0.00000	0.01	48.17	14.5	131	3.32	0.37

NA = Not Available, HQn = Hazard Quotient based on the NOAEL, HQl = Hazard Quotient based on the LOAEL

Foodweb Model Calculations:

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-9. Detailed great blue heron risk analysis for post-GKM spill maximum concentration.

Great Blue Heron		
Food Ingestion Rate	0.1140000	kg dw/kg bw/day
Water Ingestion Rate	0.0820000	L/kg bw/day
Sediment Ingestion Rate	0.0000000	kg dw/kg bw/day
Area Use Factor	1.0000000	

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Fish Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	16774.65	1912.31	0.00	1.70	1914.0	109.7	>109.7	17.45	<17.5
Barium	564	0.451	867.54	98.90	0.00	0.04	98.9	20.8	41.7	4.76	2.37
Beryllium	0.627	0.00158	0.75	0.08	0.00	0.00	0.1	NA	NA	NA	NA
Cobalt	4.36	0.03	4.53	0.52	0.00	0.00	0.5	3.89	7.8	0.133	0.067
Copper	9.9	0.0277	80.28	9.15	0.00	0.00	9.2	47	61.7	0.19	0.15
Iron	12100	16.7	12504.17	1425.47	0.00	1.37	1426.8	NA	NA	NA	NA
Lead	9.6	0.0157	10.76	1.23	0.00	0.00	1.2	0.45	11.3	2.73	0.11
Manganese	279.7	0.413	289.07	32.95	0.00	0.03	33.0	977	>977	0.0338	<0.03
Mercury	0.0228	0.0002	2.90	0.33	0.00	0.00	0.3	0.49	1.2	0.67	0.28
Nitrate-Nitrite-Nitrogen	NA	46.4	46.40	5.29	NA	3.80	9.1	NA	NA	NA	NA
Silver	0.0778	0.0005	0.13	0.02	0.00	0.00	0.0	7	35	0.0022	0.00044
Strontium	133.1	4.57	411.56	46.92	0.00	0.37	47.3	NA	NA	NA	NA
Vanadium	28.1	0.03	0.93	0.11	0.00	0.00	0.1	11.4	>11.4	0.0095	<0.01
Zinc	34.3	0.191	496.51	56.60	0.00	0.02	56.6	14.5	131	3.90	0.43

NA = Not Available, HQn = Hazard Quotient based on the NOAEL, HQl = Hazard Quotient based on the LOAEL

<u>Foodweb Model Calculations:</u>

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-10. Detailed American bullfrog risk analysis for post-GKM spill maximum concentration.

Bullfrog

Food Ingestion Rate	0.4300000 kg dw/kg bw/day
Water Ingestion Rate	0.3800000 L/kg bw/day
Sediment Ingestion Rate	0.0050000 kg dw/kg bw/day
Area Use Factor	1.0000000

Maximum Concentrations

Ecological Contaminant of Concern	Sediment Concentration (mg/kg)	Water Concentration (mg/L)	Invertebrate Concentration (mg/kg)	Fish Concentration (mg/kg)	Food Dose (mg/kg-bw/d)	Sediment Dose (mg/kg-bw/d)	Water Dose (mg/kg-bw/d)	Total Dose (mg/kg/day)	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	NOAEL HQ_n	LOAEL HQ_l
Aluminum	16200	20.7	19213.2	16774.65	8261.68	81.00	7.87	8350.54	109.7	>109.7	76.12	<76.1
Barium	564	0.451	668.904	867.54	373.04	2.82	0.17	376.04	20.8	41.7	18.08	9.02
Beryllium	0.627	0.00158	0.743622	0.75	0.32	0.0031	0.00	0.32	NA	NA	NA	NA
Cobalt	4.36	0.03	5.17096	4.53	2.22	0.02	0.01	2.26	3.89	7.8	0.580	0.289
Copper	9.9	0.0277	23.0274966	80.28	34.52	0.05	0.01	34.58	47	61.7	0.74	0.56
Iron	12100	16.7	14350.6	12504.17	6170.76	60.50	6.35	6237.60	NA	NA	NA	NA
Lead	9.6	0.0157	1.337898341	10.76	4.63	0.05	0.01	4.68	1.13	11.3	4.14	0.41
Manganese	279.7	0.413	331.7242	289.07	142.64	1.40	0.16	144.20	977	>977	0.1476	<0.2
Mercury	0.0228	0.0002	0.0270408	2.90	1.25	0.00011	0.00	1.25	0.026	0.078	47.95	15.98
Nitrate-Nitrite-Nitrogen	NA	46.4	NA	46.40	19.95	NA	17.63	37.58	NA	NA	NA	NA
Silver	0.0778	0.0005	0.014004	0.13	0.06	0.00039	0.00	0.06	7	35	0.0083	0.0017
Strontium	133.1	4.57	157.8566	411.56	176.97	0.67	1.74	179.37	NA	NA	NA	NA
Vanadium	28.1	0.03	33.3266	0.93	14.33	0.14	0.01	14.48	11.4	>11.4	1.270	<1.3
Zinc	34.3	0.191	121.1844955	496.51	213.50	0.17	0.07	213.74	14.5	131	14.74	1.63

NA = Not Available, HQn = Hazard Quotient based on the NOAEL, HQl = Hazard Quotient based on the LOAEL

Foodweb Model Calculations:

Total Dose = (Dose Food + Dose Sediment + Dose Water) x AUF

Food Dose= Food Concentration of Most Contaminated Food Item x Food Ingestion Rate

Sediment Dose = Sediment Concentration x Incidental Soil Ingestion Rate

Water Dose = Water Concentration x Water Ingestion Rate

Table B-11. Calculation of benthic invertebrate concentration based on post-GKM spill maximum sediment concentration and literature based bioaccumulation factors.

COPC	Invertebrate Bioaccumulation Factors (dw)	Source	Maximum Sediment Concentration (mg/kg)	Invertebrate Concentration (dw)
Aluminum	1.186	USEPA 1999	16200	19213.2
Barium	1.186	USEPA 1999	564	668.904
Beryllium	1.186	USEPA 1999	0.627	0.743622
Cobalt	1.186	USEPA 1999	4.36	5.17096
Copper	$Ci = 10^{(0.278+1.089(\log Csed))}$	Bechtel Jacobs 1998b	9.9	23.03
Iron	1.186	USEPA 1999	12100	14350.6
Lead	$Ci = 10^{(-0.515+0.653(\log Csed))}$	Bechtel Jacobs 1998b	9.6	1.34
Manganese	1.186	USEPA 1999	279.7	331.7242
Mercury	1.186	USEPA 1999	0.0228	0.0270408
Nitrate-Nitrite-Nitrogen	NA	--	NA	NA
Silver	0.18	Hirsch 1998	0.0778	0.014004
Strontium	1.186	USEPA 1999	133.1	157.8566
Vanadium	1.186	USEPA 1999	28.1	33.3266
Zinc	$Ci = 10^{(1.89+0.126(\log Csed))}$	Bechtel Jacobs 1998b	34.3	121.18

Table B-12. Calculation of aquatic plant concentration based on post-GKM spill maximum sediment concentration and literature based bioconcentration factors.

COPC	Sediment Concentration (dw)	Plant Bioconcentration Factors (dw)	Source	Plant Concentrations (dw)
Aluminum	16200	1	assumed	16200
Barium	564	0.15	Baes et al 1984	84.6
Beryllium	0.627	$Cp = 10^{(-0.536+0.7345*(\log Csed))}$	USEPA 2007	0.0094
Cobalt	4.36	0.0075	USEPA 2007; Bechtel Jacobs 1998a	0.0327
Copper	9.9	$Cp = 10^{(0.668+0.394*(\log Csed))}$	Bechtel Jacobs 1998a	3.87
Iron	12100	1	assumed	12100
Lead	9.6	$Cp = 10^{(-1.328+0.561*\log(Csed))}$	USEPA 2007; Bechtel Jacobs 1998a	0.17
Manganese	279.7	0.079	USEPA 2007; Bechtel Jacobs 1998a	22.0963
Mercury	0.0228	$Cp = 10^{(-0.966+0.544*\log(Csed))}$	Bechtel Jacobs 1998a	0.014
Nitrate-Nitrite-Nitrogen	NA	NA	--	NA
Silver	0.0778	0.014	USEPA 2007	0.0010892
Strontium	133.1	1	assumed	133.1
Vanadium	28.1	0.00485	Bechtel Jacobs 1998a	0.136285
Zinc	34.3	$Cp = 10^{(1.575+0.554*\log(Csed))}$	Bechtel Jacobs 1998a	266.4

Table B-13. Calculation of fish concentration based on post-GKM spill maximum surface water concentration and literature based bioconcentration factors.

COPC	Fish Bioconcentration Factors	Source	Surface Water Concentration (mg/L)	Fish Concentration (mg/kg) (dw)
Aluminum	2.7	Geometric mean- Cleveland et al 1986; Cleveland et al., 1991	20.7	55.89
Barium	633	USEPA 1999	0.451	285.48
Beryllium	62	Geometric mean - Thompson et al 1972; USEPA 1978, USEPA 1992b	0.00158	0.10
Cobalt	1	assumed	0.03	0.03
Copper	2840	USEPA 1999	0.0277	78.67
Iron	1	assumed	16.7	16.70
Lead	640	AQUIRE 2002	0.0157	10.05
Manganese	1	assumed	0.413	0.41
Mercury	14120	USEPA 1999	0.0002	2.82
Nitrate-Nitrite-Nitrogen	1	assumed	46.4	46.40
Silver	112	USEPA 1996	0.0005	0.06
Strontium	60	NCRP 1996	4.57	274.20
Vanadium	1	assumed	0.03	0.03
Zinc	2556	USEPA 1999	0.191	488.20

Table B-14. Calculation of fish concentration based on post-GKM spill maximum sediment concentration and literature based bioaccumulation factors.

COPC	Fish Bioaccumulation Factors (mg/kg dw)	Source	Sediment Concentration (mg/kg)	Fish Concentration (mg/kg)
Aluminum	1	assumed	16200	16200.00
Barium	1	assumed	564	564.00
Beryllium	1	assumed	0.627	0.63
Cobalt	1	assumed	4.36	4.36
Copper	0.1	Krantzberg and Boyd 1992	9.9	0.99
Iron	1	assumed	12100	12100.00
Lead	0.07	Krantzberg and Boyd 1992	9.6	0.67
Manganese	1	assumed	279.7	279.70
Mercury	3.25	Cope et al. 1990	0.0228	0.07
Nitrate-Nitrite-Nitrogen	NA	--	NA	NA
Silver	1	assumed	0.0778	0.08
Strontium	1	assumed	133.1	133.10
Vanadium	NA	--	28.1	NA
Zinc	0.147	Pascoe et al. 1996	34.3	5.04

Table B-15. Calculation of fish concentration based on benthic invertebrate concentration calculated from post-GKM spill maximum sediment concentration and literature based bioaccumulation factors.

COPC	Benthic Invertebrate Concentration (mg/kg)(dw)	Fish Dose (mg/kg)
Aluminum	19213.2	518.76
Barium	668.904	18.06
Beryllium	0.743622	0.02
Cobalt	5.17096	0.14
Copper	23.0274966	0.62
Iron	14350.6	387.47
Lead	1.337898341	0.04
Manganese	331.7242	8.96
Mercury	0.0270408	0.00
Nitrate-Nitrite-Nitrogen	NA	NA
Silver	0.014004	0.00
Strontium	157.8566	4.26
Vanadium	33.3266	0.90
Zinc	121.1844955	3.27

Minnow

Average Body Weight	0.9	g
Food Ingestion Rate	0.0270	kg/kg-bw-day

Table B-16. Total fish concentration used in post-GKM spill maximum risk analysis.

COPC	Fish Concentration from Sediment	Fish Concentration from Surface Water	Fish Concentration from Ingestion of Food	Total Fish Concentration (mg/kg)
Aluminum	16200.00	55.89	518.76	16774.65
Barium	564.00	285.48	18.06	867.54
Beryllium	0.63	0.10	0.02	0.75
Cobalt	4.36	0.03	0.14	4.53
Copper	0.99	78.67	0.62	80.28
Iron	12100.00	16.70	387.47	12504.17
Lead	0.67	10.05	0.04	10.76
Manganese	279.70	0.41	8.96	289.07
Mercury	0.07	2.82	0.00	2.90
Nitrate-Nitrite-Nitrogen	NA	46.40	NA	46.40
Silver	0.08	0.06	0.00	0.13
Strontium	133.10	274.20	4.26	411.56
Vanadium	NA	0.03	0.90	0.93
Zinc	5.04	488.20	3.27	496.51